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# The Canadian Entomologist

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*Editor:* DR. EUGENE MUNROE, Room 335, Science Service Building, Carling Avenue, Ottawa.

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# The Canadian Entomologist

Vol. XC

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No. 9

## The Behaviour of the Mountain Pine Beetle, *Dendroctonus monticolae* Hopk., During Mating, Egg Laying, and Gallery Construction<sup>1</sup>

By R. W. REID<sup>2</sup>

### Introduction

The biology of the mountain pine beetle was studied in 1956 and 1957 near Invermere, in the East Kootenay region of British Columbia. The host tree was lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.). The technique used permitted direct observation of mating, egg laying, and gallery construction. The sex ratio was also investigated under natural conditions and in cages. The most important previous work on the biology of this insect was done by De Leon, Bedard, and Terrell (1934).

### Methods

Sheets of fresh inner bark, 5 x 10 x 3/16 ins. were placed between pieces of glass. The edges were bound with friction tape which sealed in the bark and kept it fresh for as long as three weeks. The plates were kept in a vertical position. Bedard (1933) used a similar technique to study the habits of Douglas-fir beetle larvae. A small strip was cut from the lower edge to allow insertion of the beetles. Only young, recently emerged unmated adults were used.

### Mating Behaviour

Females excavated galleries for one day before the males were introduced. When a male was placed in a gallery he immediately moved up to the female and commenced to jostle her. The male later backed down the gallery to a wide spot, turned around and backed up the gallery to the female where he continued the courtship chiefly by stroking her with his metathoracic legs. Depending on the responsiveness of the female, mating occurred within a few minutes to several hours. Mating took place when the male and female assumed the positions illustrated diagrammatically in Fig. 2. A similar mating position has been described for *Dendroctonus micans* and *Pityogenes chalcographus* (Francke-Grossmann 1950). Pairs remained connected for periods varying from 10 to 60 seconds but usually for about 30 seconds. The majority of the matings occurred in the upper end of the gallery. In the first day mating usually occurred more than once. During the next few days matings occurred once per day but much less frequently after the females commenced egg laying. Observations were made on 31 mating pairs. With one exception, all spermatheca in mated females contained sperm.

A few general observations were made on the number of matings and number of eggs laid. One female which was set up in an observation plate in the morning, mated a day later and laid 57 viable eggs before being allowed to mate again. During the second mating the female was immediately receptive to a male and mating occurred within less than a minute. The female then laid 54 viable eggs and after a third mating she laid 44 viable eggs. The observations made did not show how many fertile eggs she was capable of laying after a single mating.

<sup>1</sup>Contribution No. 452, Forest Biology Division, Science Service, Department of Agriculture, Ottawa, Canada.

<sup>2</sup>Forest Biology Laboratory, Calgary, Alberta.

Under natural conditions the male often leaves the gallery after the first few days. The female will not come in contact with another male while she is in that egg gallery. Such females can emerge and establish another gallery and lay viable eggs without being mated again. This was determined by removing males from galleries soon after mating had taken place. Each of these females was able to lay viable eggs in a second gallery without being mated again. Females of *Dendroctonus pseudotsugae* and *D. micans* do not require mating again when they establish their second brood (Bedard 1933, Francke-Grosmann 1950).

Sperm remain viable for periods of at least a year in the spermatheca. This has been shown in mated females which ceased egg laying due to cold weather in the fall; the following spring they extended the same galleries and laid viable eggs. Francke-Grosmann (1950) found that sperm in the spermatheca of *D. micans* are able to survive the winter.

Young beetles within brood galleries seldom mate. Examination of freshly emerged females showed that less than 1 per cent had mated before they emerged. The mated females were the last to emerge. Five females were examined on 24 different days during the period of emergence.

#### Gallery Construction and Oviposition

Galleries of the mountain pine beetle have been described by Hopkins (1909), Evenden *et al.* (1943), and Hopping (1946). Within the observation plates the female bit off small particles of inner bark and outer sapwood from the upper end of the gallery. This boring dust collected around the female and was kicked behind her. When a quantity of boring dust had accumulated she pushed it down the gallery to the male. She then moved forwards and continued working at the upper end. If the male was close to the entry hole, he pushed the boring dust out of the gallery. When the beetles were some distance from the entry hole the boring dust was compacted in the gallery by the male; if he was not present the female did this. The beetles usually kept 6 to 8 inches of gallery at the upper end free of boring dust.

Egg laying commenced within 3 or 4 days following the first mating. A similar time lapse was observed in the field. When mating first occurred the female had massive flying muscles and the reproductive system was not fully developed. In the 3-day period the wing muscles degenerated, the fat body decreased in size, and the ovarioles enlarged. The space formerly occupied by the wing muscles and fat body was filled by the ovarioles and the expanded ventriculus (Reid, 1958). During this interval the female continued extending the gallery but with increased vigour.

The egg laying behaviour of the female is illustrated diagrammatically in Fig. 1. Before depositing an egg she excavated a small niche in one side of the gallery at the extreme upper end (A). The female then backed down the gallery (B) to a previously constructed wide spot where she reversed (C) and backed to the upper end (D). At the upper end she laid an egg in the niche (E). The female then repeated the turning process (F, G, H) and returned to the upper end where she continued to elongate the gallery (I) before excavating another egg niche (J). The female did not pack the egg niche with boring dust deliberately but this material soon covered the egg and became packed into the niche in the process of extending the gallery.

Fig. 3 is a photograph of an egg gallery with the boring dust removed. Equal numbers of eggs are generally deposited on both sides of the gallery.



In short galleries the number of eggs per inch increases rapidly, reaches a peak, and then slowly decreases at the upper end of the gallery. In long galleries (greater than 12 inches) there is considerable variation in numbers of eggs per inch. These conclusions are based on careful examination of 60 galleries.

Unmated females were placed in caged logs and their behaviour studied. These beetles extended their galleries more slowly than mated beetles. The galleries were 2 to 9 inches long and were frequently in a zig-zag pattern. Some

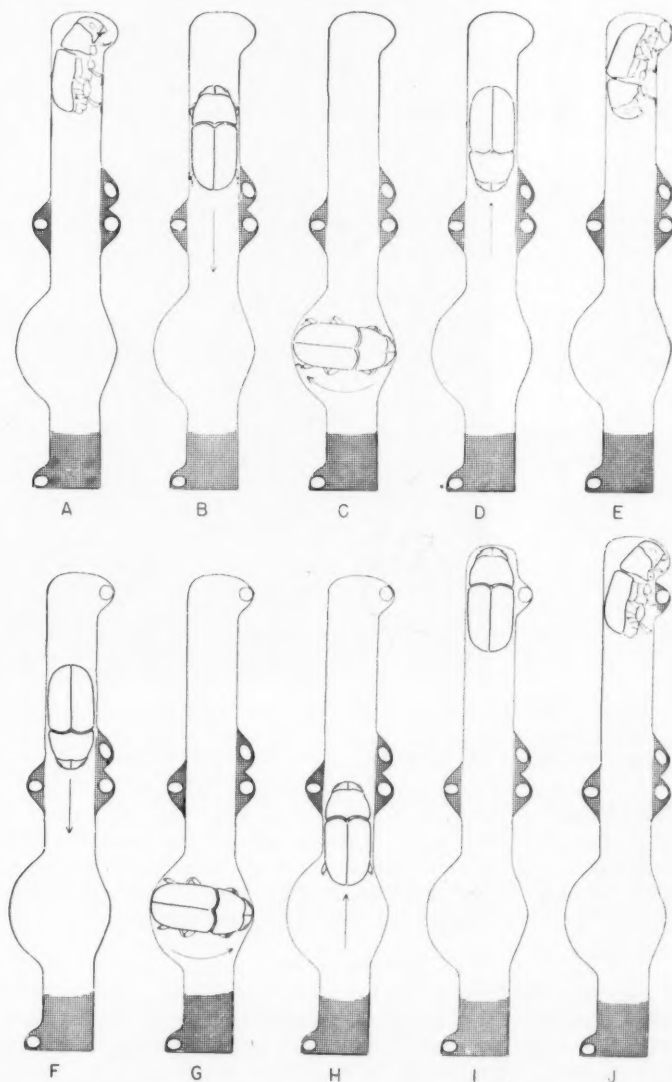


Fig. 1. Sequence of movements associated with egg laying by the mountain pine beetle.



Fig. 2. Mating position of male and female (upper) mountain pine beetles within a gallery.



Fig. 3. Portion of a mountain pine beetle gallery with the outer bark and boring dust removed. Eggs are visible in the egg niches. (Photo by P. S. Debnam).

females constructed as many as 4 galleries of this type. The first one was usually kept free of boring dust. The changes of the internal organs from flying condition to egg laying condition were not as rapid in unmated females as in mated females. Some unmated females showed internal changes after several weeks. A few laid eggs but they were not viable and soon collapsed.

#### The Sex Ratio

It is common for females to outnumber males in populations of adult bark beetles. Bedard (1933) found that parent Douglas-fir beetles were in the ratio of 63:100, males to females, in freshly attacked trees. De Leon *et al.* (1934) found a ratio of approximately 64:100 in parent adults of the mountain pine beetle in newly attacked trees. Francke-Grosmann (1950) reported that young adults in mature broods of *D. micans*, during mid-summer, were in the

ratio of 20 : 100. After the broods had overwintered the ratio was commonly 5 : 100. The author found that parent beetles in recently attacked lodgepole occurred in the ratio of 5 : 100. Most workers agree that this inequality in the sex ratio is overcome by the polygamous habits of the male. Bedard (1933), and Vité and Rudinsky (1957) suggest that there is a greater mortality of males than females because males are exposed to natural control factors for a longer period during their search for females. This conclusion was based on observations on the Douglas-fir beetle where the sex ratio just prior to emergence was 100 : 100 but after attack was 63 : 100. Bedard did not state whether the original broods had been reared under caged or exposed conditions.

In early spring of 1955, 1956 and 1957 logs were caged from a number of trees infested the previous year to check the sex ratio of the mountain pine beetle. The emerging beetles were collected daily and placed in separate vials. The sex was determined by the presence or absence of the stridulating mechanism. This structure is located on the 7th abdominal tergite of the male (Hopkins 1909). The total number of adults emerging from these cages in 1955, 1956, and 1957, was 1653, 874 and 1213 respectively. The ratios of male to female beetles each year was 42 : 100, 42 : 100, 50 : 100, and were approximately the same as in the daily and half-hourly collections. It was mentioned earlier that the sex ratio of the mountain pine beetle in freshly attacked trees was approximately 50 : 100. This suggests that there is little differential mortality during the flight. It also suggests that the inequality in the sex ratio results from conditions which were effective prior to the emergence of the brood.

#### Acknowledgments

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## Catalogue of Lederer Types of Pyralidae in the British Museum (Natural History) with Selections of Lectotypes (Lepidoptera)<sup>1</sup>

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The Pyralidae described by Lederer in *Wiener Ent. Monatschr.* 7: 331-502 (1863) came mainly from the Imperial collections in Vienna and from the private collections of Zeller, Kaden and Felder. Of these, the Zeller and Felder collections are now in the British Museum (Natural History), but the Lederer types contained in them have not previously been segregated or marked. I have therefore systematically done this, marking holotypes or selecting lectotypes where this was necessary and suitable material is present. The species are listed below in the order in which Lederer gives them, with page references.

*Homalochroa aestivalis*, p. 332. Lederer does not state the source of his material.

A male in the Felder collection bears the labels: "Venezuela" and "Homalochroa aestivalis m." I consider this to be the holotype.

*Vitessa ternatica*, p. 335. The holotype was a female in the Felder collection. I have not located it.

*Stemmatophora vibicalis*, p. 338. The holotype bears the following labels: "Type"; "Zeller Coll."; "Ceylon (Nietner). Dohrn: Nov. 54"; "Stemmatophora vibicalis Led., t. 7, f. 4, p. 48, Ceylon (Nietner)" [this and the previous label in Zeller's hand]; and "Pyralidae Brit. Mus. Slide No. 1454 ♀"

*Paracme insulsalis*, p. 339. Holotype, female, Felder collection, with labels "Ningpo" and "Paracme insulsalis m.", the latter in Lederer's hand.

*Omphalocera cariosa*, p. 339. Holotype, male, Felder collection, with labels "Nord Amer."; "Omphalocera cariosa m.", in Lederer's hand; and "Type Omphalocera cariosa Led. det. E.L.M. 1955"

*Asopia torridalis*, p. 342, 457. Lectotype, male, Felder collection, with labels: "Ceylon"; and "Asopia torridalis m." in Lederer's hand. The abdomen is missing, but the specimen is well preserved otherwise.

*Asopia rufulalis*, p. 343. Holotype, male, Zeller collection, with labels: "Asopia rufulalis Led. t. 7, f. 3. Valdivia"; "Blepharocerus rosellus Blanch Valdivia don Dohrn 9/61.", both in Zeller's hand; and "Type".

*Hemimatia atramentalis*, p. 347, 459. Holotype, female, Felder collection, with labels: "Venezuela Mor."; "Venezuela"; and "Hemimatia atramentalis", the last in Lederer's hand.

*Deuterollyta conspicialis*, p. 359. Lectotype, male, Felder collection, with labels: "Rio"; "Deuterollyta conspicialis ♂", the latter in Lederer's hand. The type lacks the left fore and hind wings.

*Cacographis osteolalis*, p. 360. Lectotype, male, Felder collection, with labels: "Venezuela, Lindig"; "Lindig 809."; "Novara CXX f. 14. Cacographis osteolalis Led. Pyral. p. 360."

*Botys proceralis*, p. 367, 460. Lectotype, male, Felder collection, with labels: "Rubiundalis Schl. aff. Phönicealis n. sp." Gn. determ. Nord America" and "Pyrausta proceralis Led. Pyr. 77 N. Amer.", the latter in Zeller's hand.

*Botys similalis*, p. 367, 460. Lectotype, male, Zeller collection, with labels "rubricalis Hb. ♂ similalis Led. olim", in Lederer's hand and "Pyrausta rubricalis H. 106 Tr. 7, 174. Led. Pyr. p. 168. similalis Led.", in Zeller's hand.

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<sup>2</sup>Principal Entomologist.

- Botys niepoldalis*, p. 368, 460. Holotype, male, Zeller collection, with labels "Type"; "Zell. Coll. 1884"; "Niepoldalis Led., t. 8, f. 6, Hnm 87", the last in Zeller's hand.
- Botys fodinalis*, p. 369, 461. Holotype, male, Zeller collection, with labels, "California v. Müller"; "Botys fodinalis Led. t. 8 f. 9", in Zeller's hand; "Zell. Coll. 1884"; and "Type".
- Botys teneralis*, p. 370, 462. Lectotype, male, Felder collection, with labels: "Venezuela"; "teneralis", in Lederer's hand; and "Rothschild Bequest, B.M. 1939-1." Lederer's citation of the locality is erroneous. Both the specimens in the Felder collection are from Venezuela; the one from the Zeller collection is from Colombia. As the last was evidently regarded as a variant by Lederer and was so labelled by Zeller, I have not chosen it as type, despite the fact that Hampson's concept of the species was based on it. Of the Felder specimens, the female, on which the figure was apparently based, has had the abdomen largely destroyed by museum pests; the male is smaller and more fulvous, and is perhaps the same as *Liopasia apicenotata* ab. 1 of Hampson.
- Botys myopicalis*, p. 370, 462. Lectotype, female, Felder collection, with labels: "Venezuela Mor."; "myopicalis m." in Lederer's hand; and "Rothschild Bequest, B.M. 1939-1."
- Botys insipidalis*, p. 370, 463. Lectotype, male, Zeller collection, with labels: "Columbien, M. Berol. 1850"; "Insipidalis Led. t. 8, f. 15 Columbia", in Zeller's hand; "Botys insipidalis Lederer. Type"; "Zell. Coll. 1884"; and "Type". Lederer also mentions a poor specimen in the Vienna Museum, so I think it best to consider the present specimen a lectotype. There is a pupal skin associated with the lectotype.
- Botys artificialis*, p. 370, 463. Holotype, female, Zeller collection, with labels: "Type"; "Botys artificialis Led. 80 t. 8, 16. Brasil". The type locality is evidently erroneous, as other available material is from tropical Asia.
- Botys glebalis*, p. 371, 464. Holotype, male, Felder collection, with label, "Botys glebalis m." in Lederer's hand. There is no locality label on the specimen. The locality given by Lederer is evidently erroneous, for the type is evidently conspecific with the African *Sylepta megastigmalis* Hampson. Hampson's name falls (new synonymy).
- Botys mancalis*, p. 371, 464. There are two syntypes in the Felder collection. As this group is under revision by Mr. Hahn W. Capps, Washington, D.C., I refrain from making a lectotype selection.
- Botys nereidalis*, p. 371, 465. Holotype, male, Felder collection, with labels: "Amboina Doll."; "Amboina Dol."; and "Botys nereidalis m.", the last in Lederer's hand.
- Botys bistrionalis*, p. 371. Lectotype, female, Felder collection, with labels: "Austral."; "Nova Holland Scott"; "bistrionalis m. lucusalis Wlk. p. 722."; "bistrionalis Led.". The status of this specimen depends on the wording of the International Rules of Zoological Nomenclature, undefined at the time of writing. Lederer proposed his name as a substitute for *lucusalis* Walker, not because the latter was a homonym but because he thought it insufficiently described to deserve recognition. The wording of the Bradley Draft Rules would require the type of *bistrionalis* to be that of *lucusalis*. The specimen cited here is not the type of *lucusalis* but is obviously one of the ones studied by Lederer, whereas he at most gave a cursory examination to the type of *lucusalis*.



- Botys maccalis*, p. 371, 466. Holotype, male, Felder collection, with labels: "Silhet"; "maccalis m." in Lederer's hand; and "maccalis Led." As I have pointed out elsewhere, this is a South American species, identical with *Polygrammodes eximia* Jones.
- Botys tranquillalis*, p. 371, 466. Holotype, male, Felder collection, with labels: "Ternate Feld."; "tranquillalis m." in Lederer's hand; and "Rothschild Bequest B.M. 1939-1." The sex is given wrongly by Lederer.
- Botys obumbratalis*, p. 372, 467. Lectotype, male, Felder collection, with labels: "Nord Amer." and "obumbratalis m.", the latter in Lederer's hand.
- Botys aequalis*, p. 372, 468. Holotype, male, Felder collection, with labels: "Ost-Indien"; "Botys aequalis m.", in Lederer's hand; and "Rothschild Bequest B.M. 1939-1." Lederer gives the sex wrongly.
- Botys paupellalis*, p. 372, 469. Holotype, male, Felder collection, with labels: "Ost.-Ind."; "Botys paupellalis m.", in Lederer's hand; and "Rothschild Bequest, B.M. 1939-1."
- Botys plebejalis*, p. 373, 469. The status of this name is questionable; Lederer proposed it on p. 373, and repeated it on p. 469 with the statement that he had meanwhile decided the specimen was a variety of *B. phaeopteralis* Guenée, and that the name should be withdrawn. Lederer does not state the location of the specimen. Assuming that the name is available, a male in the Felder collection with labels "Venezuela Mor."; "Venezuela"; "phaeopteralis" in Lederer's hand; and "Rothschild Bequest B.M. 1931-1." is probably the type, and I have so labelled it.
- Botys scitalis*, p. 373, 470. Holotype, female, Zeller collection, with labels "Brasilien" in an unknown hand, and "Scitalis Led. t. 10, f. 11. Columbia" in Zeller's hand. Another specimen, no doubt from the same lot, has labels "Brasilien, M. Berol. 1850" and "N?sp. Gn. determ. Columbia Mus. 1850". Other material seen is from southern Brazil, and it is likely that Brazil, not Colombia, is the true country of origin of the type.
- Botys integralis*, p. 373, 470. The holotype is listed as a damaged male in the Felder location. Not located.
- Botys sanguiflualis*, p. 374, 470. Lederer says there were two syntypes, in the Kaden and Felder collections. The species he figures is *Sylepta mnemusalis* (Walker); there is no specimen of this in the Felder collection, where under the name *sanguiflualis* there are two poor specimens of the Oriental *Sylepta sellalis* (Guenée). The latter species is, obviously what Lederer described from two poor females in the Felder collection as *Botys consimilalis*, but under that name there is a specimen of the American *Sylepta amando* (Cramer), with labels reading: "Amboina Doll."; "Amboina Dol."; "Botys consimilalis m.", in Lederer's hand; and Felder's name label "consimilalis Led." *S. amando* disagrees completely with Lederer's diagnosis of *consimilalis*, but might conceivably have been taken by him to be a variant of *S. mnemusalis*. As the figure of *sanguiflualis* certainly does not represent any specimen now in the Felder collection, and as I have not seen the specimen in the Kaden collection, now presumably in Leningrad, I refrain from selecting a lectotype, but I think it almost certain that this specimen of *S. amando* is a syntype of *B. sanguiflualis*, not of *B. consimilalis* and that the labels have been accidentally transposed.
- Botys consimilalis*, p. 374, 471. Lectotype, female, Felder collection, with Felder's name label "sanguiflualis Led.". As explained above, I have little doubt that the labels attached to the specimen of *S. amando* discussed under *B. sanguiflualis* really belong to the present specimen, and I select it as

- lectotype, restricting the type locality to Amboina. The other specimen under the label *sanguiflualis* is a male, with labels "Lor."; "*B. sanguiflualis* Led. affin." The genitalia are retracted and the specimen could have been taken for a female. I think this is likely the other syntype, from Ternate.
- Botys ustalis*, p. 375, 471. Lectotype, male, Felder collection, with labels: "Amboina"; "*ustalis* m." in Lederer's hand; and "Rothschild Bequest B.M. 1939-1." The genitalia are retracted and the specimen was mistaken for a female by Lederer.
- Botys faustalis*, p. 375, 471. Holotype, male, Felder collection, with labels: "Amboina Dol."; "*Botys faustalis* m.", in Lederer's hand; and "Rothschild Bequest B.M. 1939-1."
- Botys trigalis*, p. 375. Lectotype, male, Felder collection, with labels: "Amboina Dol."; and "*trigalis* Led. orissusalis !?Wlk.", the latter in Lederer's hand. The abdomen has been eaten out by museum pests.
- Botys principalis*, p. 375, 471. Holotype, female, Felder collection, with labels: "Nord Amerika"; "*Botys principalis* m.", in Lederer's hand; and "Rothschild Bequest B.M. 1939-1." The left hing wing of the type is missing. Lederer spells the name "*principalis*" on p. 375 and on the plate, but "*principalis*" on p. 471, p. 498 and in his manuscript label. I have no doubt that Hampson was right in choosing "*principalis*" as the correct spelling. The species is not the same as *Botys chromalis* Guenée, though closely related.
- Botys spoliatalis*, p. 375, 473. Holotype, female, Felder collection, with labels: "Nord Amer."; "*Botys spoliatalis* m.", in Lederer's hand; and "Rothschild Bequest B.M. 1939-1."
- Botys dissipatalis*, p. 376, 474. Holotype, female, Felder collection, with labels: "Amboina Doll."; "Amboina, Dol."; and "*dissipatalis* m.", the last in Lederer's hand.
- Botys adipalis*, p. 376, 475. Lectotype, male, Felder collection, with labels: "Amboin Dol."; and "*Botys adipalis*", the latter in Lederer's hand.
- Botys fatualis*, p. 376, 475. Lectotype, female, Felder collection, with labels: "Java"; and "*Botys fatualis* m.", the latter in Lederer's hand. In my opinion this is a different species from *Botys adipalis* Lederer.
- Botys ? gratalis*, p. 376, 475. Lectotype, female, Felder collection, with labels: "Amboina Dol."; "*Botys gratalis* m.", in Lederer's hand; and "Rothschild Bequest B.M. 1939-1."
- Botys affinitalis*, p. 376, 475. Lectotype, female, Felder collection, with labels: "Austral Angas"; "*Bot. affinitalis* m.", in Lederer's hand; and "Rothschild B.M. 1939-1." The female syntype is missing.
- Marasmia cicatricosa*, p. 386. Holotype, male, Felder collection, with labels: "Java Dol."; "*Marasmia cicatricosa*" in Lederer's hand; and "Rothschild Bequest B.M. 1939-1."
- Polythlipta macralis*, p. 389, 477. Holotype, male, Felder collection, with labels: "Amboina Doll."; "Amboina Dol."; "*Polythlipta macralis* m."; in Lederer's hand; and "Rothschild Bequest B.M. 1939-1." The variant "*maceratalis*" given on p. 477 is evidently a typographical error.
- Polythlipta ossealis*, p. 389, 477. The holotype, a male, was in the Felder collection but is now lost. The holotype of *macralis* stands with Felder's name-label "*ossealis* Led."
- Auxomitia mirificalis*, p. 391. Holotype, female, Felder collection, with labels: "Nikobar"; "*Auxomitia mirificalis* m.", in Lederer's hand; "*mirificalis* Led." (Felder's name-label); and "Rothschild Bequest B.M. 1939-1."

- Meroctena staintonii*, p. 392. Holotype, female, Felder collection, with labels: "Amboina Doll."; "Meroctena Staintonii ♀", in Lederer's hand; "Staintonii Led." (Felder's name-label); and "Rothschild Bequest B.M. 1939-1."
- Phacellura arguta*, p. 401, 478. Holotype, male, Felder collection, with labels: "Nord Amer."; "Phacellura arguta m.", in Lederer's hand; and "arguta Led." (Felder's name-label). The abdomen has been largely destroyed by museum pests.
- Phacellura advenalis*, p. 401, 478. Lectotype, female, Felder collection, with labels: "Shanghai"; "Phacellura advenalis m.", in Lederer's hand; "Felder colln."; and "Type".
- Caprinia felderi*, p. 401, 478. Holotype, male, Felder collection, with labels: "Amboina Doll."; "Amboina Dol."; and "Caprinia felderi m.", the last in Lederer's hand.
- Glyphodes doleschali*, p. 402, 478. Lectotype, male, Felder collection, with labels: "Amboina Doll."; "Amboina Dol."; and "Glyphodes Doleschali Led.", the last in Lederer's hand. On p. 478 the termination is given as -ii. The other syntype is lost.
- Glyphodes zelleri*, p. 402, 478. Lectotype, male, Felder collection, with labels: "Amboina Doll."; "Amboina Dol."; "Zelleri m.", in Lederer's hand; and "Zelleri Led." (Felder's name-label).
- Heterocnephes scapularis*, p. 402. Lectotype, male, Felder collection, with labels: "Amboina Doll."; "Heterocnephes scapularis m.", in Lederer's hand; and "scapularis Led." (Felder's name-label).
- Heortia dominalis*, p. 403. Lectotype, male, Felder collection, without labels. The specimen bearing Lederer's and Felder's name-labels is from Amboina, whereas Lederer cites Ternate as the type locality. The lectotype has no locality label, but agrees much better with Lederer's figure than does the Amboina specimen. I have no doubt that Lederer had both specimens before him and that the lectotype is from Ternate but has lost its locality label.
- Chloauges suralis*, p. 405. Lectotype, male, Felder collection, with labels: "Amboina Doll."; "Amboine Dol."; "Chloauges suralis m.", the last in Lederer's hand. There are syntypes in the Zeller collection, also from Amboina and conspecific with those in the Felder collection, but those in the Zeller collection are faded.
- Analyta albicillalis*, p. 406. Holotype, male, Felder collection, with labels: "Amboina Doll."; "Amboina Dol."; "Analyta albicillalis m."; "Rothschild Bequest B.M. 1939-1."
- Spargeta basalticis*, p. 407. The type material, from Amboina, was in the Felder collection, but is lost.
- Analthes semitritalis*, p. 407. Holotype, male, Felder collection, with labels: "210"; "Java"; "Analthes semitritalis m.", in Lederer's hand; and Felder's name-label "semitritalis Led." Lederer gives the type-locality "Amboina" but I think there is no doubt this is a mistake. The present specimen is the only one in the Felder collection, and it agrees excellently with Lederer's figure. Lederer states specifically that he saw only a single male in poor condition.
- Rhimphalea sceletalis*, p. 411. Lectotype, male, Felder collection, with labels: "Amboina Doll."; "Amboina Dol."; "Rhimphalea sceletalis m.", in Lederer's hand.

- Anarmodia longinqualis*, p. 413. Lectotype, male, Felder collection, with labels: "Venezuel."; "Anarmodia longinqualis m.", in Lederer's hand; and Felder's name-label "longinqualis Led."
- Terastia subjectalis*, p. 416, 480. Lectotype, female, Felder collection, with labels: "Silhet"; "Terastia subjectalis m.", in Lederer's hand; Felder's name-label "subjectalis Led."; and "Rothschild Bequest B.M. 1939-1."
- Ischnurges illustralis*, p. 418. Holotype, male, Felder collection, with labels: "Austral."; "Ischnurges illustralis m.", in Lederer's hand; Felder's name-label "illustralis Led."; and "Rothschild Bequest B.M. 1939-1."
- Euclasta maceratalis*, p. 423, 481. Lectotype, male, Felder collection, with labels: "Austral."; "P. elegantalis Macleay N. Holland"; "Euclasta maceratalis m.", in Lederer's hand; "Rothschild Bequest B.M. 1939-1."
- Bradina impressalis*, p. 425, 481. Lectotype, male, Felder collection, with labels: "Amboina Doll."; "Amboina Dol."; "impressalis m.", in Lederer's hand; and "Rothschild Bequest B.M. 1939-1."
- Bradina selectalis*, p. 425, 481. Lectotype, male, Felder collection, with labels: "Amboina Doll."; "Amboin Dol."; "Bradina selectalis m."; and "Rothschild Bequest B.M. 1939-1."
- Erilita modestalis*, p. 426. Lectotype, male, Zeller collection, with labels: "Erilita modestalis Led. 135 t. 16 f.3. Amboina"; and "Zell. Coll. 1884". Lederer does not state the source of his material, but this and three other specimens from Amboina are undoubtedly syntypes. There are also four specimens under the name *modestalis* in the Felder collection, but without Lederer's label; one is labelled "Amboina Doll." the others are without locality.
- Pleonectusa tabidalis*, p. 426, 481. Lederer mentions only four specimens from the Vienna Museum. The Felder collection contains a specimen from Amboina with Lederer's manuscript label; this specimen probably is really a syntype, but I refrain from selecting it as lectotype as it is not mentioned in the original publication.
- Pleonectusa sodalis*, p. 426, 481. Lederer lists *sodalis* and *admixtalis* together on p. 481 and 482, saying that they are the same and that he saw two males, in the Felder collection and the Imperial collections. On p. 426 he lists *sodalis* separately, giving the locality Amboina, whereas he gives Ceylon and Nicobars for *admixtalis*. The only specimen in the Felder collection is from the Nicobars, and thus cannot be the type of *sodalis*. As there is no independent description or figure of *sodalis* this must probably in any event be considered an objective synonym of *admixtalis*.
- Platamonia ampliatalis*, p. 427. Lectotype, female, Felder collection, with labels: "Amboina Doll."; "Amboine Dol."; "Platamonia ampliatalis m.", in Lederer's hand; and "Rothschild Bequest B.M. 1939-1."
- Orphnophanes productalis*, p. 428. Lectotype, male, Felder collection, with labels: "Amboina Doll."; "Amboin Dol."; "productalis m." in Lederer's hand; and "Rothschild Bequest B.M. 1939-1."
- Entephria praeuptalis*, p. 428. Holotype [?] male, Felder collection, with labels: "Amboina Doll."; "Amboina Dol."; "Entephria praeuptalis m.", in Lederer's hand; and "Rothschild Bequest B.M. 1939-1." The type is fragmentary. There are two other specimens, also in poor condition, though somewhat better than the type, in the Felder collection. These may be syntypes but they are without locality and there is no direct evidence that Lederer saw them.

- Coptobasis textalis*, p. 430, 482. Holotype, male, Felder collection, with labels: "Amboina Doll."; "Amboin Dol"; "Coptobasis textalis m.", in Lederer's hand, and "Rothschild Bequest B.M. 1939-1."
- Coptobasis spretalis*, p. 430, 482. Lectotype, male, Felder collection, with labels: "Amboina Doll."; "Amboin Dol"; "Coptobasis spretalis ♂", in Lederer's hand; and "Rothschild Bequest B.M. 1939-1." The two syntypes are of different species: the lectotype appears to be the same as *Sylepta odontosticta* Hampson, which falls; the other syntype is a male of *Botys machinalis* Felder and Rogenhofer.
- Piletocera violalis*, p. 431. Lectotype, male, Felder collection, with labels: "Amboina Doll." and "Rothschild Bequest B.M. 1939-1." This is not the specimen with Lederer's name-label, which is a female, and so marked by Lederer, although he says the genus is known to him only in the male sex.
- Aediodes quaternalis*, p. 434, 483. Lederer mentions only a male and a female in the Felder collection; but the four specimens under this name in the Felder collection, one with Lederer's name label, are not conspecific with the species figured and described, but are specimens of *Bocchoris dispersalis* (Zeller). There is no specimen of the figured species in the Felder collection. I therefore select Lederer's excellent figure (*Wiener Ent. Monatschr.* 7, Pl. 17, Fig. 1) to represent the type of *Aediodes quaternalis*, with type locality Amboina.
- Gonocausta zephyralis*, p. 436. Lectotype, male, Felder collection, with labels: "Gonocausta zephyralis m.", in Lederer's hand; and "Rothschild Bequest B.M. 1939-1."
- Diathrausta profundalis*, p. 438. Lectotype, male, Felder collection, with labels: "Diathrausta profundalis m.", in Lederer's hand; and "Rothschild Bequest B.M. 1939-1." This specimen has no locality label, but almost matches the figure, whereas a second syntype, with label "Amboina", less closely resembles the figure. The lectotype lacks the head.
- Cirrhochrsta aetherialis*, p. 441. Holotype? male, Felder collection, with labels: "Amboina Doll."; "Amboine Dol"; "Cirrhochrsta aetherialis m. = Margaronia brizoalis Wlk.", in Lederer's hand; "Rothschild Bequest B.M. 1939-1." Lederer does not mention the source of his material, but this specimen agrees with the figure and is at least a syntype. If other syntypes exist this should be regarded as the lectotype.
- Cirrhochrsta pulchellalis*, p. 441. Lectotype, female, Felder collection, with labels: "Amboina Doll."; "Amboine Dol"; "pulchellalis m." in Lederer's hand; and "Rothschild Bequest B.M. 1939-1." The abdomen is lacking. A badly rubbed specimen from Amboina in the Zeller collection is probably a syntype.
- Physematia concordalis*, p. 447. The type, from the Nicobars, should be in the Felder collection, but I cannot locate it.
- Dichocrocis frenatalis*, p. 448. Holotype, male, Felder collection, with labels: "K"; "Nikobar"; "Dichocrocis frenatalis m.", in Lederer's hand; "Rothschild Bequest B.M. 1939-1." The abdomen and the wings of the left side are lacking.
- Synclita gurgitalis*, p. 449, 483. Holotype, male, Felder collection, with labels: "Synclita gurgitalis m.", in Lederer's hand; "Rothschild Bequest B.M. 1939-1."; and "Type Synclita gurgitalis Led.", the last written by E. L. Martin.



- Hydrocampa scitalis*, p. 451, 483. Lectotype, male, Zeller collection with labels: "Type"; "Hydrocampa scitalis Led. 159. Amboina, Java", in Zeller's hand; "Zell. Coll. 1884".
- Parapoynx aptalis*, p. 452, 485. Lectotype, male, Zeller collection, with labels: "Columbien M. Ber. 1850"; "Parapoynx aptalis Led. p. 160 N. Amer.", in Zeller's hand; and "Zell. Coll. 1884".
- Parapoynx fragmentalis*, p. 453, 485. Holotype, female, Felder collection, with labels: "Venezuela Mer."; "272"; "VI 12"; "Parapoynx fragmentalis Led." in Lederer's hand; and "Rothschild Bequest B.M. 1939-1."
- Cymoriza loricatalis*, p. 453, 486. Lectotype, male, Felder collection, with labels: "Amboina Doll."; "Cymoriza loricatalis m.", in Lederer's hand; and "Rothschild Bequest B.M. 1939-1."
- Cataclysta opulentalis*, p. 453, 486. Lederer cites the type material as three males in the Felder collection. I believe this is a mistake. The specimen associated with this name is of an Asiatic species quite unlike Lederer's figure, with the locality "Ambarawa." In the Zeller collection, on the other hand, there is a male reasonably similar to Lederer's figure, with labels "Columbia, M. Ber 1850"; "Cataclysta opulentalis Led. 161, 5. 18, 7. N. Amer.", in Zeller's hand; and "Zell. Coll. 1884". Other similar material was examined and described by him and the species is usually cited as North American. I consider this specimen to be a syntype and choose it as lectotype. This will ensure the use of the name in its traditional sense.
- Cataclysta moniligeralis*, p. 454, 487. Holotype, male, Zeller collection, with labels: "Columbien M. Berol. 1850"; *Cataclysta moniligeralis* Led. 162. t. 18, f. 10", in Zeller's hand; and "Zell. Coll. 1884".
- Margarosticha pulcherrimalis*, p. 454. Lectotype, female, Felder collection, with labels: "Amboina Doll."; "Margarosticha pulcherrimalis m.", in Lederer's hand; and "Rothschild Bequest B.M. 1939-1."
- Homophysa fulminalis*, p. 455, 487. Lectotype, male, Felder collection, with label: "Rothschild Bequest B.M. 1939-1."
- Scybalista trifunalis*, p. 455, 487. Lectotype, male, Felder collection, with labels: "Venezuela Mor."; "Venezuela"; "Scybalista trifunalis m.", in Lederer's hand; Felder's name-label "trifunalis Led."; and "Rothschild Bequest B.M. 1939-1."

#### Summary

Lederer types of Pyralidae in the British Museum (Natural History) are catalogued. Holotypes of 39 species are listed, 44 lectotypes are selected, and a figure is selected to represent the type of one species; types of three species are considered lost and syntypes of four species are discussed without selection of a lectotype.

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**Observations on *Aphidecta obliterata* (L.) (Coleoptera: Coccinellidae), a Predator of Conifer-Infesting Aphidoidea<sup>1</sup>**

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During 1950 and 1951 the writer collaborated with officers of the Commonwealth Institute of Biological Control in studies of the predators of *Adelges* (*Dreyfusia*) *piceae* (Ratz.) and *Adelges* (*Dreyfusia*) *nüsslini* (Börner) in Europe. These studies preceded the importation of the more important predacious species into Canada and their release against *A. piceae*. Observations on one of these predators, *Aphidecta obliterata* (L.) (Coleoptera: Coccinellidae), are given in this paper.

**Nomenclature**

This species, first described by Linnaeus (1758, page 367) as *Coccinella obliterata*, was subsequently included in the genus *Adalia*; later Weise (1893) described the genus *Aphidecta* and, in 1899, the genus *Aphidecta* for it. The last has been accepted generally and is used in this paper.

**Distribution and Prey Species**

*A. obliterata* occurs throughout western Europe, including southern Scandinavia and the British Isles. It is a predator of *Adelges piceae* (Van Dinter, 1951; Delucchi, 1953) and of *Adelges nüsslini* (Hofmann, 1938; Schneider-Orelli, 1939) on fir, *Abies alba* Mill.; of *Cinara pinicola* (Walk.) on larch (Harrison, 1913); and of *Adelges* (*Gilletteella*) *cooleyi* (Gillette) on Douglas fir, *Pseudotsuga taxifolia* (Poir.) Britton, and on Sitka spruce, *Picea sitchensis* (Bong.) Carr. (Laidlaw, 1936; Francke-Grosmann, 1950). Therefore, its prey includes mostly conifer-infesting species.

The present investigation was made in the Vosges Mountains of eastern France, where feeding on *A. nüsslini*, *A. piceae*, and *A. cooleyi* was observed. Unless otherwise stated, all observations were of specimens that had been associated with *A. nüsslini*. Details of the life-history of this adelgid in the Vosges are being published elsewhere (Wylie, in press).

**Description of Stages**

Detailed descriptions of the adult were published by Weise (1892), Portevin (1931), and other European authors. Among the adults collected in the present study there was a continuous gradation in color from specimens with uniformly light-brown elytra to others with elytra deep brown except for lighter areas at the base and along the costa. No specimens with uniformly dark-brown elytra were observed, though these have been noted (Weise, 1892; Nicholson, 1912). The significance and inheritance of the different color forms were not investigated.

The eggs are oval and bright yellow-orange. They are laid singly or linearly in groups of up to 10 in an upright position on the infested bark or needles. The four larval instars were described by Van Emden (1949) and Van Dinter (1951). The posterior end of the pupa is attached to the bark or needles by a sticky fluid secreted by the last-instar larva immediately before it pupates. The pupal morphology was described by Van Dinter (1951).

**Annual Cycle**

There is one generation of *A. obliterata* each year in the Vosges. Gravid females appear on infested trees early in April and feed on developing adelgids.

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Egg-laying begins shortly after April 15, reaches a peak early in May, and ends about June 15. Duration of the egg stage is influenced by weather conditions and averages about seven days. Larvae are present in late April, May, and June. Pupation begins early in June, and the duration of the pupal stage averages about seven days. Adults begin emerging in mid-June, mate, and in early July disperse from infested firs; thereafter, none was observed on trees infested by *Adelges nüsslini*, *Adelges piceae*, or *Adelges cooleyi* until the following spring. It is unlikely that there is a second generation on another host later in the summer; however, an egg of this species that subsequently hatched was discovered on July 4 on a fir infested by *Adelges nüsslini*, but this probably represented abnormally late oviposition by an over-wintered female. Several hundred mated females that emerged in June and July and were held in the laboratory and in field cages did not oviposit during the summer.

The behaviour of the adults after they leave infested trees in July is not known. Nicholson (1912), Murray (1931), and Buck (1955) collected specimens in autumn from a variety of conifers in Britain. The adults may hibernate gregariously, for Murray (1931) observed large numbers on Scots pine, *Pinus sylvestris* L., in Scotland in autumn.

#### Durations of Immature Stages

The duration of each immature stage was determined by isolating freshly laid eggs individually in two-inch vials. An abundant supply of adelgid-infested twigs was supplied in each vial during larval development. Tests were made in a room where the temperature ranged from 15°C. to 19°C. Fifteen progeny of one beetle were studied simultaneously.

Minimum and maximum durations, in days, of each immature stage were: egg, seven and eight; first-instar larva, four and five; second-instar larva, three and four; third-instar larva, three and four; fourth-instar larva and prepupa, nine and 12; pupa, 10 and 12. Total developmental time for the 15 specimens ranged from 38 to 41 days.

The effect of temperature on the durations of the immature stages is evident when the present results are compared with those of Van Dinter (1951) and Delucchi (1953), who reared specimens at constant temperatures of 20°C. or higher. The present results would probably be modified in nature by wider temperature fluctuations and, in some cases, by low host population densities that would increase the time spent by the beetle larvae searching for food.

#### Fecundity

Ten *A. obliterata* females, collected from April 6 to 9 before there was any oviposition by the species in nature, were isolated individually in screened vials at 15°C. to 19°C. and 65 per cent to 85 per cent relative humidity. Each was provided continuously with infested bark, and eggs were removed frequently to limit cannibalism. The number of eggs laid per female ranged from 153 to 293 and the oviposition periods from 40 to 53 days. The daily oviposition rate of each adult increased until early May, then decreased; the peaks coincided approximately with the maximum number of unhatched adelgid eggs, and oviposition ceased when this food supply was nearly exhausted. To determine whether the duration of the oviposition period was correlated with food intake by the female, four of the beetles that had stopped laying late in May were confined singly after June 6 with adults and eggs of *Adelges cooleyi*, which were then numerous on needles of Douglas fir; the other six beetles were, as before, supplied with bark infested with *Adelges nüsslini*, which then was mostly in the non-edible, neosistens stage. None of these six females laid any eggs, whereas those that fed on *Adelges cooleyi* laid 15 to 49 eggs each. The food

eaten by the female apparently influenced the number of eggs laid. A similar result with *Chilocorus bipustulatus* (L.) was recorded by Hecht (1936). The maximum number of eggs laid by a female in the present test was 342, (293 while the adult was feeding on *Adelges nüsslini* and 49 while on *Adelges cooleyi*). This total contrasts with the maximum of 98 recorded in laboratory studies by Van Dinter (1951). Natural reproductive capacity is probably less than that observed experimentally, where time loss by females searching for food was negligible.

Repeated copulation during the oviposition period was reported by Palmer (1914) and Putman (1955) as essential to maintain egg-laying by *Adalia frigida* (Schönh.) (= *melanopleura* Lec.) and *Stethorus punctillum* Weise, respectively. With *A. obliterata* there is, apparently, no interim copulation, as only females were found in nature during the egg-laying period.

#### Adult Longevity

The females mate soon after emerging, in June and July, and do not oviposit until the following spring. Longevity after egg-laying was determined for the 10 females studied in the previous experiment: they were held in a field cage throughout the summer and fed adults and eggs of *Adelges cooleyi* and *Adelges piceae* when available, water, and a 10 per cent sugar solution. Eight adults died during July and August, and two were alive when the experiment ended on September 13. Overwintered adults were observed in decreasing numbers until mid-July on trees infested with *Adelges nüsslini*. It is unlikely that any females overwinter a second time.

Male longevity was not investigated; however, no males were found in April or May, and as freshly emerged specimens mate in June and July and as copulation during oviposition is not required for egg production, it is probable that none overwinter.

#### Feeding Habits

Sessile neosistens of *Adelges nüsslini* are not attacked. Adults, eggs, and second- and third-instar sistentes are eaten by the adult beetles and by all larval instars; and first-instar "crawlers", progredientes, and sexuparae by the large larvae, especially those of the fourth instar. First- and second-instar larvae of *A. obliterata* pierce the egg chorion with their mandibles and draw out the contents, leaving the empty shell on the bark; third and fourth instars ingest the whole egg. "Crawlers" are completely consumed, whereas adults and developing larvae are pierced and sucked, the empty skin remaining on the bark.

Cannibalism was observed in laboratory rearings: eggs were attacked occasionally by freshly hatched larvae and, less often, by female beetles; and mature, inactive larvae were occasionally eaten by third or early-fourth instars. Egg destruction in nature is probably negligible as those in each egg mass usually hatch almost simultaneously, and larvae do not feed for at least an hour after they have hatched; in addition, most of the eggs are laid on the needles, and searching for food by larvae is limited largely to the bark.

#### Habitat Preference

Habitat selection by *A. obliterata* and other insect predators was discussed in a previous paper (Wylie, in press). The apparent preference of *A. obliterata* for a twig rather than a stem habitat indicates its adaptation as a predator of *Adelges nüsslini* rather than of *Adelges piceae*, though it was found occasionally in pure stem infestations of the latter adelgid.

### Relation to Other Adelgid Predators

*A. obliterata* was one of several insect predators of *Adelges nusslini* found in this study. On infested twigs, where *A. obliterata* was most abundant, larvae of *Leucopis griseola* (Fall.) (Diptera: Chamaemyiidae) were also numerous; and on infested stems larvae of *Pullus impexus* (Muls.) (Coleoptera: Coccinellidae), *Laricobius erichsonii* Rosenh. (Coleoptera: Derodontidae), and *Neoleucopis obscura* (Hal.) (Diptera: Chamaemyiidae) were occasionally abundant. Experimentally, larvae of each of these species were occasionally attacked by those of *A. obliterata*; however, little evidence of this in nature was observed. *Anatis ocellata* (L.) and *Exochomus quadripustulatus* (L.) (Coleoptera: Coccinellidae) occasionally destroyed the larvae and pupae, respectively, of *A. obliterata*; however, because of their scarcity on most adelgid-infested trees, neither of these greatly influenced populations of *A. obliterata*.

### Parasites

Two parasites of *A. obliterata* were reared: a phorid, *Phalacrotophora berolinensis* Schmitz, and a mermithid of the genus *Hexameris*.

*P. berolinensis* was recorded in England by Colyer (1952) and in Switzerland by Delucchi (1953) as a gregarious internal pupal parasite of *A. obliterata*. The phorid eggs are laid externally on the ventral surface beneath the host wing pads. They hatch within 24 hours, and the larvae enter the host near the site of eclosion, molt twice, emerge ventrally between the head and thorax, drop to the ground, and pupate, usually within an inch of the surface. Delucchi (1953) reported that the total larval period averaged three weeks; however, in the present study mature phorid larvae emerged five days after they had hatched. An equally short larval period was recorded by Colyer (1952). The phorid adults emerge in July and August. Over half of the beetle pupae collected were parasitized by this species. Usually, two or three phorid larvae matured in each host, though as many as seven emerged occasionally. Sucking by the phorid adults of *A. obliterata* pupae, reported by Colyer (1952), was also observed though its significance was not investigated.

*Hexameris* sp. emerged from fourth-instar larvae of *A. obliterata* and entered the soil. Apparently only this instar was attacked, as no mermithids were obtained from younger field-collected larvae. Approximately 10 per cent of the fourth-instar larvae were parasitized. Though one beetle larva dissected contained two small mermithids, only one worm per host emerged in all rearings.

### Summary

*Aphidecta obliterata* (L.), a predator of *Adelges nusslini* (Börner), has one generation each year in eastern France. The gravid female lays up to about 300 eggs on the bark and needles of infested trees, and the larvae hatch in about seven days and feed on all stages of *A. nusslini* except the sessile neosistens. Pupae form on the bark and needles and adults emerge in about a week, i.e., usually late in June. The adults soon mate and disperse from the infested trees and do not return until the following spring. The population density of *A. obliterata* was not appreciably affected by other predators with which it was associated, but over half of the pupae were parasitized by the phorid *Phalacrotophora berolinensis* Schmitz and a smaller proportion by a mermithid of the genus *Hexameris*.

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### Additions to Official List of Common Names of Insects

Of the 56 common names proposed in No. 4 of Vol. 3 of the *Bulletin of the Entomological Society of America* as additions to the official list of common names of insects of the Entomological Society of America the following ten were submitted by the Committee on Common Names of Insects of the Entomological Society of Canada:

- Apion longirostre* Olivier, hollyhock weevil;  
*Galerucella decora* (Say), gray willow leaf beetle;  
*Saperda bipunctata* R. Hopping, Saskatoon borer;  
*Eumerus strigatus* (Fallen), onion bulb fly;  
*Pleuromeura borealis* Felt, balsam shoot-boring sawfly;  
*Anisota virginensis* (Drury), pink-striped oakworm;  
*Archips fervidana* (Clemens), oak webworm;  
*Endrosis sarcitrella* (Linnaeus), white-shouldered house moth;  
*Hofmannophila pseudospretella* (Stainton), brown house moth;  
*Lampronia rubiella* (Bjerkand), raspberry bud moth.

## Insect Surveys of Clovers, Alfalfa, and Birdsfoot Trefoil in Eastern Ontario<sup>1</sup>

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Studies on insects affecting seed and forage production of legume crops were begun in eastern Ontario in 1951. Since little was known of what species of insects were of economic importance in these crops in this area, the primary objects of the studies were to determine what species of insects damage the forage crop legumes, their seasonal occurrence and abundance, and something of their importance. Observations were made as well on some of the beneficial insects found in association with the crops.

Five species of legumes were surveyed for insects in one or more years from 1951 to 1954: red clover, *Trifolium pratense* L.; alsike clover, *Trifolium hybridum* L.; Ladino clover, *Trifolium repens* L.; alfalfa, *Medicago sativa* L.; and birdsfoot trefoil, *Lotus corniculatus* L. Special attention was given to red clover and alfalfa because they are the most widely grown forage crop legumes in eastern Ontario. Ladino clover is seldom grown for seed or hay crops but is often used in pasture mixtures. Very little alsike clover has been grown in recent years, and birdsfoot trefoil has only recently been grown as a forage crop.

Several workers in the eastern United States have recently reported on surveys of insects in clovers and alfalfa, namely, Kerr and Stuckey (1956) in Rhode Island, Shaw *et al.* (1953) in Massachusetts, and Kulash and Hanson (1949) in North Carolina. In New York State, Neunzig and Gyrisco (1955) conducted insect surveys in birdsfoot trefoil.

There is little literature on the insects damaging clovers or alfalfa in eastern Ontario. MacVicar *et al.* (1952) showed that insecticides directed against the insect complex in red clover gave increased yields of seed. In a similar study, Braun *et al.* (1953) did not obtain increased yields of seed, apparently because of a severe infestation of the clover seed midge, *Dasyneura leguminicola* (Lint.), which was not controlled by the insecticides.

In southwestern Ontario, Arnott (1948) showed that the clover seed weevil, *Miccotrogus picrostris* (F.), was an important pest of alsike clover; its importance was demonstrated further by Pielou (1950), Heming (1952), Heming *et al.* (1953), and Moreland (1954). Putman (1953) found that the meadow spittlebug, *Philaenus leucophthalmus* (L.), was one of the most abundant insects in the Niagara Peninsula, where it attacked alfalfa as well as a great variety of other plants. The clover leaf weevil, *Hypera punctata* (F.), the lesser clover leaf weevil, *Hypera nigrirostris* (F.), the clover root curculio, *Sitona hispidula* (F.), and the clover root borer, *Hylastinus obscurus* (Marsh.), studied by Hudson and Wood (1924, and 1925) and Hudson (1926a, and b), respectively, were not considered of great economic importance in clovers in southwestern Ontario by these authors.

In Quebec, Dean and Morrison (1957) found rather large infestations of the clover root borer, *H. obscurus*, in some red clover fields throughout the western, central, and southern parts of the Province.

All the preceding species of insects are found in clovers or alfalfa in eastern Ontario.

<sup>1</sup>Contribution No. 3834, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada; from a thesis submitted to the Department of Entomology and Limnology, Cornell University, in partial fulfillment of the requirements for an M.Sc. degree.

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### Methods

The surveys were largely made in Carleton and Renfrew counties of eastern Ontario in an area extending from Ottawa to about 20 miles southeast of the City and 60 miles west. They were made from May to September, twice each month in 1951 in clovers and alfalfa, twice each month in 1954 in red clover, alfalfa, and birdsfoot trefoil, and two or four times each month in 1952 and 1953 in all five crops. A total of 11 fields of red clover, eight of alfalfa, two of Ladino clover, two of alsike clover, and two of birdsfoot trefoil were surveyed in the four years.

Sampling was done by making systematic sweeps with an insect sweep net 14 inches in diameter. Each sweep of the net brushed the upper parts of the plants, the net being swung in a five-foot arc, horizontally, in one direction. One hundred sweeps were made per field, 25 in each quarter, on each survey date. Most of the fields were about 10 to 15 acres in size. The contents of each 100-sweep sample were placed in cyanide bottles to kill the insects and then transferred to cardboard cartons. In the laboratory the insects were sorted and counted, representative specimens of each species being identified by the following officers of the Entomology Division, Ottawa: Thysanoptera and Homoptera, Drs. B. P. Beirne and W. R. Richards; Heteroptera, Dr. L. A. Kelton and Mr. W. N. Smith; Coleoptera, Mr. R. de Ruelle; Hymenoptera, Drs. O. Peck and R. Lambert; and Diptera, Dr. J. R. Vockeroth.

### Results and Discussion

#### *Injurious Insects*

Twenty-seven species of injurious insects were collected, 26 of them attacking red clover; 14, alfalfa; 16, Ladino clover; 12, alsike clover; and nine, birdsfoot trefoil (Table I). Most of the species listed in Table I are well-known pests of forage crop legumes in one or more areas of Canada or the United States. Some of the species were sufficiently numerous in one or more years to be of economic importance in eastern Ontario; others were present only in small numbers and the damage they caused was slight. A discussion of the seasonal occurrence and abundance of the more important pests follows:

*Orthoptera*.—Grasshopper populations were low from 1951 to 1953. In 1954, there was a marked increase in the populations of two species, *Melanoplus femur-rubrum* (DeG.) and *Melanoplus bivittatus* (Say). Serious damage was observed in one field only, a field of birdsfoot trefoil at the Central Experimental Farm, Ottawa. The main damage was to the nearly mature seed pods, which were chewed open and their seeds consumed, about five per cent of the pods being damaged or destroyed.

*Hemiptera (Heteroptera)*.—This order was represented by four species of mirids, which were common in all five crops. The tarnished plant bug, *Liocoris lineolaris* (Beauv.) (*Lygus lineolaris* (P. de B.)), was more abundant than the others and hence was probably the most destructive mirid. Because populations of *L. lineolaris* in the five legume crops were about equal, only those in red clover are discussed in this paper.

Adults of the tarnished plant bug wintered within or near the fields of red clover, becoming active in early May. These adults averaged five to 15 per 100 net-sweeps until late June, when nymphs of the first generation began to mature. Nymphs of the first generation were first observed in early June; they averaged 95 and 60 per 100 net-sweeps during mid-June in 1952 and 1953, respectively. In 1952, the last record obtained in first-growth red clover was on June 24, just before the last of the survey fields was harvested; none or almost

TABLE I

Insects commonly attacking forage crop legumes in eastern Ontario as recorded  
in insect surveys, 1951 to 1954

Insect	Red clover	Alfalfa	Ladino clover	Alsike clover	Birdsfoot trefoil
Orthoptera					
Locustidae					
<i>Melanoplus femur-rubrum</i> (DeG.)	x	x	x	x	x
<i>Melanoplus bivittatus</i> (Say)	x	x	x	x	x
Thysanoptera					
Thripidae					
<i>Frankliniella tritici</i> (Fitch)	x	x			
<i>Haplothrips niger</i> (Osb.)	x				
<i>Thrips tabaci</i> Lind.	x				
Heteroptera					
Miridae					
<i>Adelphocoris lineolatus</i> (Goeze)	x	x	x	x	x
<i>Adelphocoris rapidus</i> (Say)	x	x	x	x	x
<i>Liocoris lineolaris</i> (Beauv.)	x	x	x	x	x
<i>Plagiognathus chrysanthemi</i> (Wolff)	x	x	x	x	x
Homoptera					
Aphidae					
<i>Anuraphis bakeri</i> (Cowen)	x				
<i>Acyrthosiphon pisum</i> (Harr.)	x	x	x	x	x
<i>Therapsiphon trifolii</i> (Monell)	x				
Cercopidae					
<i>Philaenus leucophthalmus</i> (L.)	x	x	x	x	x
Cicadellidae					
<i>Empoasca fabae</i> (Harr.)	x	x	x		x
Lepidoptera					
Olethreutidae					
<i>Grapholitha interstinctana</i> (Clem.)	x				
Coleoptera					
Chrysomelidae					
<i>Systema frontalis</i> (F.)	x		x		
Curculionidae					
<i>Hypera meles</i> (F.)	x	x	x	x	
<i>Hypera nigrirostris</i> (F.)	x		x	x	
<i>Hypera punctata</i> (F.)	x				
<i>Miccotrogus picirostris</i> (F.)			x	x	
<i>Si ona hispidula</i> (F.)	x	x	x	x	
<i>Sitona tibialis</i> (Hrbst.)	x	x	x		
<i>Tychius stephensi</i> Schön.	x				
Scolytidae					
<i>Hylastinus obscurus</i> (Marsh.)	x				
Hymenoptera					
Eurytomidae					
<i>Bruchophagus gibbus</i> (Boh.)	x				
<i>Bruchophagus gibbus medicaginis</i> Kolobova		x			
Diptera					
Ceratomyiidae					
<i>Dasyneura leguminicola</i> (Lint.)	x				
<i>Dasyneura trifolii</i> (Loew)	x		x		
Total species recorded	26	14	16	12	9

none of the first-generation nymphs had matured. In 1953, the last record obtained in first-growth red clover was also on June 24; adults of the first generation averaged 40 per 100 net-sweeps and nymphs were still numerous, averaging 60 per 100 net-sweeps.

In second-growth red clover, first-generation adults averaged 80 per 100 net-sweeps from mid-July to early August in 1952, and 60 per 100 sweeps in 1953. Second-generation nymphs began to appear in mid-July; in the latter half of August, they averaged about 400 per 100 net-sweeps in both these years. Most of the nymphs were mature by mid-September. The second-generation adults were never so numerous as the second-generation nymphs; they averaged 250 per 100 net-sweeps in late August, 1952 and 1953, and decreased rather rapidly in numbers in early September as the crops matured. They probably moved to other feeding areas. There are only two generations of the tarnished plant bug on the five legume crops in eastern Ontario annually.

The alfalfa plant bug, *Adelphocoris lineolatus* (Goeze), was abundant only in alfalfa; adults were scarce, and nymphs were never found, in the clovers. The insect wintered as eggs in alfalfa and these hatched about mid-June. In 1952, the nymphal population peak occurred in late June, the nymphs averaging 100 per 100 net-sweeps. The first adults were found in late June and reached their peak numbers in early July. In second-growth alfalfa, adults were usually abundant until about July 10 and then averaged about five per 100 net-sweeps until early August. Second-generation nymphs began to appear in late July and were present through August; they averaged 25 and 50 per 100 net-sweeps in early August in 1952 and 1953, respectively. Adults of the second generation averaged 40 and 60 per 100 net-sweeps in mid-August in 1952 and 1953, respectively, and 20 per 100 net-sweeps in late August and early September in both these years. There were two generations of the alfalfa plant bug in 1952 and 1953.

The rapid plant bug, *Adelphocoris rapidus* (Say), was common in all five crops but was never very abundant. Its seasonal history was similar to that of *A. lineolatus*.

A fourth mirid, *Plagiognathus chrysanthemi* (Wolff), was abundant and showed no apparent preference for any one of the five legume crops. The nymphs hatch in early June, apparently from eggs laid in the fields in the previous summer. They begin to mature in late June and adults are present through July and early August, during which period they probably lay their eggs. Populations of this species were usually rather high; in late June of 1953, adults and nymphs averaged 460 per 100 net-sweeps in red clover. Equally high populations occurred in alfalfa and birdsfoot trefoil in late June and early July. The populations were about the same in 1954. There was only one generation annually.

The writer could find in the literature no reference to *P. chrysanthemi* as a pest of agricultural crops in North America. However, Blattny *et al.* (1948) reported it as one of the more important pests of alfalfa seed crops in Czechoslovakia, where it caused flowers and pericarps to shrivel and drop and the seeds that formed to be small. Neunzig and Gyrisco (1955) found the insect in birdsfoot trefoil in New York State but did not determine whether it was destructive.

*Hemiptera (Homoptera).*—Numerous species of Homoptera were collected, but only those listed in Table I were observed to feed on the legume plants.

The pea aphid, *Acyrtosiphon pisum* (Harr.), was more abundant than other aphids and was particularly attracted to red and alsike clovers. Although



it was usually present throughout each summer it was abundant for only three to four weeks in late June and July or in August. In 1951 and 1952, populations were approximately the same; maxima of 850 and 979 specimens per sample were collected from red clover and alsike clover, respectively. Populations were low in 1953 and 1954. Damage was never apparent, even in fields with maximum populations. Numbers per individual plant were almost always small.

The potato leafhopper, *Empoasca fabae* (Harr.), was present in the forage legumes from early or mid-June until late September, being most abundant during late July and August in alfalfa. A maximum of 264 specimens per sample were collected in alfalfa; this was during late August, 1952, in which year many fields of alfalfa showed symptoms of severe injury. In the other years most fields of alfalfa and the other legumes showed no damage from this insect.

The meadow spittlebug, *Philaenus leucophthalmus* (L.), which is a destructive pest of alfalfa in southwestern Ontario (Davey and Manson, 1958), was of little importance in eastern Ontario during the surveys. Nymphs, in their conspicuous spittle masses, were first apparent in early June of each year. Adults appeared in late June or early July and were still present in late September, being most abundant in July and August. The maximum number of adults collected during the survey was 65 per sample; this was in red clover on July 18, 1952.

*Lepidoptera*.—The only species of Lepidoptera observed to damage any of the five legume crops to a significant degree was the clover head caterpillar, *Grapholitha interstinctana* (Clem.), a pest of red clover. Damage from the few larvae that were found in the heads was slight. Only an occasional caterpillar of other species was captured by sweeping and none was observed to feed on the legume plants in the field.

*Coleoptera*.—Nine species of Coleoptera were collected but most of these were not abundant and appeared to cause only slight damage. The red-headed flea beetle, *Systema frontalis* (F.), was rather abundant in red clover during 1952 and 1953. A maximum of 171 adults per sample were collected in 1953 on August 7; they remained at this level for about five weeks from late July until late August. The adults of this flea beetle damage the leaves of red clover, especially the leaflets immediately below the clover blossoms. The injury consists of small elongate holes chewed through the upper leaf surface, leaving the lower epidermis as a transparent membrane. At times the adults feed on the blossoms, chewing off parts of the corollas. Damage to the leaves and blossoms was not severe.

The clover seed weevil, *Miccotrogus picirostris* (F.), an important pest of alsike clover in southwestern Ontario (Arnott, 1948), was found in the Ottawa area for the first time in 1953 by the writer. In 1954, the insect was collected in abundance from nursery plots of Ladino and alsike clovers at the Central Experimental Farm. This weevil was probably in the area before 1953 but was not noted, perhaps because alsike and Ladino clovers are not commonly grown. According to Moreland (1953), this species had not been found east of Victoria and Durham counties in Ontario, or in Quebec, but occurred in Nova Scotia.

The clover head weevil, *Tychius stephensi* Schönh., was common in red clover fields. Overwintered adults were found in late May or early June, some of them having hibernated within the clover fields. Adults were most abundant from mid-June through July, averaging 25 per 100 sweeps during this period in 1952 and 1953. Populations were always lower than this in August and September. Both adults and larvae damage the clover heads; the adults puncture the

unopened florets and feed on the pollen grains, and the larvae feed on the developing seed, one larva to each floret. Since the insect is not abundant, losses of red clover seed due to this species are probably slight. Arnott (1948) discussed the distribution of the insect in North America but did not determine its status as a pest of clover in southwestern Ontario.

*Hymenoptera*.—The clover seed chalcid, *Bruchophagus gibbus* (Boh.), which is almost cosmopolitan in distribution, is a common pest of red clover and alfalfa in eastern Ontario. Kolobova (1950) showed that there were two races or subspecies of the insect in Russia differing ecologically and morphologically, one attacking clover and the other, alfalfa. He considered the chalcid in clover to be the typical race of the species, naming the one in alfalfa subspecies *medicaginis*. Dr. O. Peck, Entomology Division, Ottawa, found the specimens collected in eastern Ontario in red clover and alfalfa to agree morphologically with the descriptions of the two races of Kolobova.

The chalcid attacking red clover was scarce from 1951 to 1953. In 1954, the adults were rather abundant, being easily observed about the clover blossoms in the latter half of June. During August, the adults averaged 35 per 100 net-sweeps in one field of red clover. No records were obtained on the amount of seed lost to this insect. However, numerous chalcids emerged from a sample of 1000 red clover heads brought into the laboratory in early September, indicating that a considerable percentage of the seed had been infested.

The chalcid attacking alfalfa was scarce in 1951 and 1952. In 1953, it was abundant, especially in one field in its third crop year. In this field about 10 acres of first-growth and seven acres of second-growth alfalfa were grown for seed. In the first growth, only a few seed pods contained infested seeds but the second growth was rather heavily infested. Ten per cent of the seeds threshed by hand from a sample of 500 seed pods were infested with the chalcid.

*Diptera*.—Only two species of Diptera, namely, the clover seed midge, *Dasyneura leguminicola* (Lint.), and the clover leaf midge, *Dasyneura trifolii* (Loew), were injurious. The clover seed midge was the more abundant and was a very destructive pest of red clover seed, especially in 1951 and 1952.

The larvae of the seed midge infest the florets of red clover, causing them to remain closed and the ovaries to fail to develop. This type of damage is important only when the second growth of red clover is used for seed production, and other work by the author (unpublished) showed that it is more severe in the second growth when the first growth is cut after the third week in June. In 1951, most of the seed crops of red clover in Carleton County suffered great losses because of this insect, unfavourable weather having prevented harvest of the first crop until about July 5.

Braun *et al.* (1953) have shown the amount of damage caused by this midge in one seed field at Carp, Ontario; in plots not treated with a chemical, 71 per cent of the clover heads were injured and 32 per cent of the injured heads had 50 to 100 per cent of the florets infested. In the same year, the writer examined seven other fields in Carleton County and all these were heavily infested.

In 1952, in Renfrew and Carleton counties, nine red clover seed fields were examined for larval infestations. Only four of the fields were heavily infested; the others were either free, or almost free, of infestations. The degree of damage was determined for three of the four heavily infested fields, one at Carp and two at Renfrew. In 1953, larval infestations of the midge were negligible in most red clover seed fields in Carleton and Renfrew counties; the

damage was determined for only one of the fields, which was at Carp. The percentages of florets infested with larvae per clover head in the two fields at Renfrew and the one at Carp in 1952 were 32, 47, and 42, respectively, and in the field at Carp in 1953, 18; the average number of florets per head, infested and non-infested, in the four fields was 126.

The clover leaf midge was abundant only in 1951, severely damaging 10 acres of Ladino clover at the Central Experimental Farm. Larval feeding malformed and discolored the clover leaflets, which gave a reddish tinge to the entire field.

#### Miscellaneous Insects

Seven species of leafhoppers that were constant inhabitants of the survey fields but apparently not destructive to the legume plants were: *Aphrodes bicincta* (Schrank), *Athysanus argentarius* Metc., *Doratura stylata* (Boh.), *Endria inimica* (Say), *Latalus* sp., *Macrosteles fascifrons* (Stål), and *Scaphytopius actus* (Say).

The most common of these was the six-spotted leafhopper, *M. fascifrons*, the well-known vector of aster yellows virus. This insect was collected from each of the legume species and was found from early June through September in each year of the four. Nymphs of this species were never taken in the net sweeps.

According to Osborn (1939) and Oman (1949), the other six species of leafhoppers feed on various grasses.

One species of Hemiptera, *Alydus eurinus* (Say), was very abundant in red clover and alfalfa in September, 1953. It was not observed to feed on the plants and appeared to be a predator for it moved rapidly about the plants as though searching for prey. However, according to Fracker (1918), the nymphs of *A. eurinus* have been reared on milk vetch, *Astragalus* sp., in Colorado and adults are numerous in late summer on goldenrod throughout their range. This evidence of the insect's being phytophagous is offset by its occurrence on carrion (Van Duzee, 1889).

#### Wild Pollinators

The following 16 species of wild bees visiting blooms of red clover, alfalfa, or birdsfoot trefoil were collected:—Apidae: *Bombus fervidus* (F.), *B. americanorum* (F.), *B. impatiens* Cress., *B. perplexus* Cress., *B. rufocinctus* Cress., *B. borealis* Kby., *B. affinis* Cress., and *B. terricola* Kby.; Andrenidae: *Andrena wilkella* (Kby.) and *A. vicina* Sm.; Halictidae: *Halictus confusus confusus* Sm., *H. ligatus* Say, *Lasioglossum leucozonium* (Schr.), and *Lasioglossum* sp.; Megachilidae: *Megachile frigida frigida* Sm. and *M. addenda* Cress.

All eight species of bumble bees were collected from red clover and alfalfa but only *B. fervidus* and *B. americanorum* from birdsfoot trefoil. The most commonly collected bumble bees were: *B. fervidus*, *B. americanorum*, *B. impatiens*, and *B. terricola*. One andrenid, *A. wilkella*, was especially abundant in all three crops in 1953 during July. Halictids were abundant in red clover in 1953 but scarce in the other years. Leaf-cutting bees were scarce every year; only one specimen of each of the two species listed was collected, *M. frigida frigida* in red clover, and *M. addenda* in birdsfoot trefoil.

#### Insect Predators

The most commonly collected predators were as follows: several species of Coccinellidae; three species of Hemiptera, namely, *Orius insidiosus* (Say), *Geocoris bullatus* (Say), and *Nabis ferus* (L.); and one of Neuroptera, *Chrysopa* sp.

The smallest of the predators, *O. insidiosus*, was always very abundant in the fields, especially in red clover. Nymphs of this insect were observed to feed voraciously on thrips and aphids in red clover heads. *G. bullatus* was collected only occasionally whereas *N. ferus* was usually very abundant. *Chrysopa* sp. was always rather abundant. Coccinellids were especially abundant when the pea aphid, *Acyrtosiphon pisum*, was numerous.

### Summary

Insect surveys were made in eastern Ontario in red clover, *Trifolium pratense* L., and alfalfa, *Medicago sativa* L., each year from 1951 to 1954 and in Ladino clover, *Trifolium repens* L., alsike clover, *Trifolium hybridum* L., and birdsfoot trefoil, *Lotus corniculatus* L., in two of the four years. Twenty-seven species of injurious insects were collected, 26 of which attacked red clover; 12, alsike clover; 16, Ladino clover; 14, alfalfa; and nine, birdsfoot trefoil. The species that were most abundant were: in red clover only, the clover seed midge, *Dasyneura leguminicola* (Lint.), the clover seed chalcid, *Bruchophagus gibbus* (Boh.), the clover head weevil, *Tychius stephensi* Schönh., and the red-headed flea beetle, *Systema frontalis* (F.); in alfalfa, the alfalfa plant bug, *Adelphocoris lineolatus* (Goeze), a seed chalcid, *Bruchophagus gibbus medicaginis* Kolobova, and the potato leafhopper, *Empoasca fabae* (Harr.); and in all five crops, the tarnished plant bug, *Liocoris lineolaris* (Beauv.) (*Lygus lineolaris* (P. de B.)), the pea aphid, *Acyrtosiphon pisum* (Harr.), the red-legged grasshopper, *Melanoplus femur-rubrum* (DeG.), the two-striped grasshopper, *M. bivittatus* (Say), and a mirid, *Plagiognathus chrysanthemi* (Wolff). The seasonal abundance of the more important species in their host crops is indicated and for some of the species notes on seasonal histories and economic importance are given.

Sixteen species of wild bees visiting blossoms of red clover, alfalfa, or birdsfoot trefoil were collected. The most commonly collected ones were: *Bombus fervidus* (F.), *B. americanorum* (F.), *B. impatiens* Cress., *B. terricola* Kby., and *Andrena wilkella* (Kby.).

The most commonly collected insect predators in the five crops were several species of Coccinellidae; three species of Hemiptera, namely, *Orius insidiosus* (Say), *Geocoris bullatus* (Say), and *Nabis ferus* (L.); and one neuropteran, *Chrysopa* sp.

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## On the Phylogeny and Biogeography of the Family Cupedidae (Coleoptera)<sup>1</sup>

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The phylogenetic position of the family Cupedidae (Cupesidae or Cupidae of some authors) has been the subject of much controversy. As studies have been made for the most part on the eastern genus *Cupes*, I was pleased to have an opportunity to study the western species *Priacma serrata* (Lec.) (Atkins, 1957). Several hundred males were collected near Lumby, B.C. during spring in 1956 and 1957. Many of these were dissected in order to study those features of the internal and external morphology on which much of the following discussion is based.

### Phylogeny

The Cupedidae have been assigned to numerous groups within the Coleoptera. Many earlier authors placed them in the Polyphaga; for example, LeConte and Horn (1883), and later students including Blatchley (1910) placed them in the Serricornia. Casey (1897) stated, "The affinities of *Cupes* are very obscure, but certain structures, as for example the reception of the acute prosternal process in a deep pit of the mesosternum, proclaim its marked serricorn relationship." This condition is almost absent in *Priacma*. Sharp (1909) assigned them to the Polyformia, but like many others his system was not suggested to be phylogenetic.

Ganglbauer (1903) placed the Cupedidae in the Adephaga, believing them to be a modified family of that group. Lameere (1903) placed them there under the Cupediformia which he considered as the most primitive of the Adephaga. Kolbe (1908) erected the Archostomata for their reception and included it in his division Symphytogastra of the suborder Heterophaga. Barber and Ellis (1920) agreed with the placement of Kolbe.

Sharp and Muir (1912) placed the Cupedidae in the Byrrhoidea on the basis that the male genital tube of *Cupes* is of the trilobe type, the most primitive existing in living Coleoptera. They considered them distinct from the Adephaga and the Australian genus *Omma*, but felt that the homogeneous Caraboidea were probably derived from this group.

More recently, Forbes (1926), entirely on the basis of adult structures, placed these archaic beetles in the Archostomata (which was raised to the level of a suborder) with the Micromalthidae, separating them from the Adephaga on the basis of the spiral rolling of the wing apex. Böving and Craighead (1930) also assigned them to the Archostomata because they considered that their larval structure is so ancient they must be regarded as representatives of a distinct group. Crowson (1955) also found it necessary to add this third suborder for the inclusion of the Cupedidae and Micromalthidae and feels that they possibly lost their evolutionary potential through premature specialization.

It is improbable, however, that one can arrive at a true expression of the phylogenetic relationship on the basis of one or two features, as has been the case in a few of these systems. We must consider all the important features and characteristics of the insect, as well as the palaeontological evidence.

Kolbe (1908), Leng (1920), and others have pointed out the important morphological characteristics in beetle phylogeny. In the following paragraphs I shall deal with these features individually, outlining briefly what is con-

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sidered to represent the primitive and various derived conditions and describing that which occurs in the Cupedidae with particular reference to *Priacma serrata*. I shall apply Dollo's Law which states that once a structure is lost or reduced it cannot (with rare exceptions) be regained for progressive modification.

According to Leng, the primitive tarsal condition consists of five elongate, unmodified tarsomeres. Other pentamerous types such as that found in the Cerambycidae, and any reduction in the number of tarsomeres are regarded as derivatives. The Cupedidae as a group have the pentamerous condition, although that of *Priacma* is somewhat modified. This feature, however, is not now considered to be as important an indicator of beetle phylogeny as formerly.

Leng considered the primitive elytra to be imperfectly adapted to the body, pubescent and elongate, but Crowson disagrees with this. The elytra of the Cupedidae are elongate, scaled, and shield the body quite well, as did the oldest known elytra from Upper Permian Australia.

Wings capable of sustaining flight, with little reduction in venation and numerous cross-veins, are considered primitive, while loss of flight capacity, reduction of the venation and the loss of most of the cross-veins are considered advanced. From a study of the hind wings of several Cupedidae we find that wing structure closely relates them to the Adephaga. Only in the Adephaga and Cupedidae does the media remain to the base of the wing. In the Adephaga (excluding the Haliplidae) and in the Cupedidae the apex of the cubitus has disappeared while in the Polyphaga it is fused with the fourth media. The Adephaga and Cupedidae have cross-vein r-m fully developed while it is faint or absent in the Polyphaga. Two cross-veins between the media and the cubitus enclose the oblong cell which is absent in the Polyphaga. A transverse vein at the extreme base between the 3rd and 4th anals again relates the Cupedidae and the Adephaga. In the Cupedidae alone, the costa and subcosta remain separate and a second cu-a cross-vein is present. They also diverge from the Adephaga in the preservation of the first branch of the 2nd anal as an apparent branch of the 1st anal (Forbes, 1922). The persistence of this complex venation with numerous cross-veins would tend to rank the Cupedidae as primitive among the beetles. *Priacma serrata* has a larger number of cross veins than *Cupes* (Atkins, 1958), which might indicate that *Priacma* is the more primitive of these two genera.

The most common and most primitive number of abdominal segments occurring in the Coleoptera is nine, the first eight bearing spiracles and the ninth bearing the genitalia. It is also considered that an elongate, clearly segmented body represents the condition from which the shorter more compact beetles were derived. In the Cupedidae we find nine abdominal segments in all species. In *Cupes* the 2nd and 3rd sternites of the abdomen are connate and no apparent suture exists between their pleurae. This is also the case in the Polyphaga (Ganglbauer, 1903). However, in *Priacma serrata* these two sternites are completely separate and a pleural suture is clearly visible. In both *Cupes* and *Priacma* a suture exists on each side of the prothorax between the notum and the pleurae, a primitive condition occurring elsewhere only in the Micromalthidae, Myxophaga, and the Adephaga with the exception of the Ctenostomini (Cicindelidae). Although the double gular suture is absent only in the Curculionoidea, the gular sclerite is particularly broad in *Priacma serrata*.

A primitive beetle antenna consists of eleven similar, unmodified segments. All the Cupedidae have eleven-segmented antennae although the form and length varies from unmodified and longer than the body in *Cupes concolor*

to serrate and shorter than the body in *Cupes lobiceps* (LeConte, 1874). In *Priacma serrata* the antennae are elongate moniliform-like and half the length of the body. In addition they are pubescent and not geniculate, both primitive features.

Primitive palpi presumably consist of four similar, unmodified segments whereas specialization would result in modification towards triangular or securiform terminal segments or the loss of flexibility and prominence of the structure as in the Rhynchophora. Leng (1920) considered the palpi of the Cupedidae to be derived and although the palpi of *Omma* are securiform those of *Priacma serrata* are four-segmented with only slight modification of the basal component.

Several features of beetle appendages are considered primitive including membranous lobes beneath the tarsi, empodia between the claws, distinct or exaggerated trochanters, and broad, prominent coxae articulating in open coxal cavities. Appendages without the membranous lobes and empodia, and with reduced trochanters, small coxae and closed coxal cavities are therefore derived. *Priacma serrata* lacks the membranous lobes, but has what appears to be reduced or rudimentary empodia. *Omma* has distinct bisetose empodia. *Priacma* also has prominent trochanters, large coxae and open coxal cavities. It is also worthy of note that the tarsomeres bear a dense cloak of two types of intermixed setae; some are sabre-like with longitudinal striations while others are densely plumose, similar to those on the legs of honeybees.

The structure of the central nervous system has generally been considered to reflect evolutionary changes quite reliably, although some workers question its significance in this respect. In some beetles the central nervous system consists, in addition to the head ganglia, of three thoracic ganglia and seven or eight abdominal ganglia, a condition which represents only a slight change from the primitive larval condition where a pair of ganglia occurs in each segment (Beier, 1927). On the other hand Brandt (1879) found that the Curculionidae have only two abdominal ganglia. Blanchard (1846) has shown that in the Rhynchophora there are three distinct thoracic ganglia and no separate abdominal ganglia, the latter being incorporated into the metathoracic ganglion. Kolbe (1908) considered this progressive concentration of the ganglia to be a result of the unification of the body segments to form the more compact beetles and therefore to reflect evolution towards a more specialized form. In *Priacma serrata* the central nervous system has three thoracic and eight abdominal ganglia; the terminal one serves the eighth segment and the withdrawn ninth or genital segment. This is in keeping with the definitely segmented abdomen and the theory proposed by Kolbe.

The number of Malpighian tubes in the Coleoptera is relatively constant. In general four Malpighia are present in the lower-standing families such as those of the Adephaga while six Malpighia are characteristic of higher groups such as the Clavicornia and Rhynchophora. *Priacma serrata* has four Malpighian tubes.

Edwards (1953) studied the male terminalia of *Priacma* and concluded that it indicates a diphyletic origin of the family. He feels it is possible that the ancestral forms of this group branched from the early Coleoptera prior to the divergence of the Adephaga and Polyphaga. Tanner (in Arnett, 1947) concluded that the Cupedidae could not be placed with the Adephaga because the female genitalia have the coxite and valvifer very much reduced while the paraproct and proctiger are completely lacking. Unfortunately female *Priacma serrata* have not been found and this feature could not be studied. However,

as in *Cupes*, male *Priacma* appear to have a trilobed aedeagus which is the most primitive condition found in living beetles (Sharp and Muir, 1912).

Finally, as previously mentioned, the Cupedidae must be set aside on the basis of their archaic larvae, which have six-jointed legs with one or two distinct movable claws.

#### Biogeography

Rohdendorf (1944) reports the discovery of fossil *Tschekardocoleus magnus* from Lower Permian deposits of the Ural Mountains, and showed that the autonomous family, *Tschekardocoleidae*, to which this species belongs, without a doubt corresponds to the Archostomata and seems to be related to the Cupedidae. Martynov (1933) has described *Permocupes semenovi* and *Permocupes distinctus* from the Upper Permian of Arkhangelsk as being capable of belonging to the Cupedidae and considers that they constitute the oldest remains of beetles belonging to a living family. Peyerimhoff (1909) reported the discovery in the Lower Oligocene Baltic Ambers of *Priacma tessellata*, which differs little from *Cupes capitata*. This extraordinary affinity with a living species shows that these strange beetles have varied little since the Tertiary.

The family Cupedidae includes five genera and approximately 20 species, 13 of which belong to the genus *Cupes* (Jeannel and Paulian, 1949). Their current presence in the Palearctic, Nearctic, African, Neotropical, and Australian realms indicates that at one time they attained almost world-wide distribution. It appears that the *Tschekardocoleidae* and the Cupedidae were probably the first true beetles in a world of developing forests. Present fossil evidence seems to place the origin of this group in the Permian of Eurasia. Since the unification of the Malay archipelago to form a bridge from Asia to Australia probably existed for only a short time during the Cretaceous (Ross, 1951), the ancestors of the genus *Omma* must have invaded the Australian realm at this time and remained as a distinct, isolated genus, whereas the Australian *Cupes varians* is close to the East Indian *Cupes* and is probably a recent incursion. The family could have entered North America by way of the Bering land bridge during several periods of conditions suitable for intercontinental dispersion at higher latitudes. Thence dispersion to South America during one of the many periods that the two continents were connected would have just been a matter of time.

The presence of two endemic species of *Cupes* on Madagascar indicates that the genus has crossed Mozambique Channel as it has existed at least since the Cretaceous or early Cenozoic and the genus is thought to have risen no earlier than the Eocene (Crowson, in correspondence). This crossing probably took place on or in floating timbers as it is doubtful that their flight was strong enough to cross such a substantial barrier (see Atkins, 1958).

The presence of the family in the Alleghenian, Vancouverian, and Japano-Manchurian regions and their absence as a living group in Europe, indicate that glaciation may have influenced their distribution in a manner similar to that outlined for the old Holarctic beetle fauna by Van Dyke (1939).

It is also of interest that *Priacma tessellata* of the Baltic Amber was associated with gymnosperms during the early Oligocene, as are many members of the family today.

#### Conclusion

On the basis of the relationships considered by other workers and the morphological features discussed above, it seems necessary to separate the Cupedidae from the Adephaga and Polyphaga as a group having primitive

characteristics, some of which are common to one or the other of these larger suborders and some peculiar to themselves. As their larvae and wing folding show similarity only to the Micromalthidae, the Archostomata seems to be the logical place for their inclusion. The remaining problem, therefore, is whether the Archostomata should be considered as derived from the major suborders or a transition between them; the precursor of these suborders or an early side-branch of the coleopterous family tree.

The work of King (1955) on the phylogenetic position of *Atractocerus*, indicates that the Archostomata is not the only group that must be separated from the larger suborders. The Cupedidae, however, have preserved more primitive characteristics than the Apicalae, so many in fact that they certainly cannot be considered as derivatives of any living group of beetles. This coupled with their early origin, seems to be adequate evidence that they developed before the divergence of the Adephaga and Polyphaga. However it seems doubtful that a group which has remained as stable as the Cupedidae throughout the ages could have been the basic stock of such a diverse group as the Coleoptera. It seems likely that they lost their evolutionary potential through premature specialization as Crowson suggests. That is, they were specialized in terms of the Permian insect fauna, not in terms of the ensuing Coleoptera. In this case the Cupedidae must have branched from the basic Coleopterous stock early in the order's history to form a blind evolutionary line similar to that of the Apicalae.

Munros and Munros (1952) suggest that the living genera of the Cupedidae can probably be considered derivatives of *Cupes* which have developed under restrictions. I disagree with this on the basis that the present fossil records indicate an earlier origin for *Priacma* than for *Cupes*. In addition, living *Priacma* have maintained conditions which are more archaic than those occurring in the genus *Cupes* with its 13 species.

Crowson feels that the genus *Omma* is the most primitive living beetle and has informed me that there are Lower Jurassic fossils from England related to it. The Neotropical genus *Tetraphalerus*, which also has a fossil relative in the British Isles (Oligocene), is the closest living relative of *Omma*.

On the basis of the biogeography of this group it appears that their early origin and specialization (possibly the development of elytra, smaller size relative to many insects existing at that time, and large mandibles capable of wood chewing) enabled them to fill many new and protected niches and thus contributed to their world-wide success. However, their early specialization was probably limited so that with the development of many diverse and more advanced elytra-bearing insects they became obsolete. As a result, following the reduction of their range due to glaciation, changing biotas, and competition from a more advanced insect fauna, they were unable to reclaim their earlier success.

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**A Note on the Association of Fall Cankerworm (*Alsophila pometaria* (Harr.)) with Winter Moth (*Operophtera brumata* (Linn.)) (Lepidoptera : Geometridae)<sup>1</sup>**

By C. C. SMITH<sup>2</sup>

The fall cankerworm, *Alsophila pometaria* (Harr.), and the winter moth, *Operophtera brumata* (Linn.), both feed to a great extent on the same tree species and prefer apple, *Malus* spp., red oak, *Quercus rubra* L., basswood, *Tilia* spp., white elm, *Ulmus americana* L., and Norway maple, *Acer platanoides* L. They also have similar life-histories and habits (Smith 1950 and 1953). Both lay their eggs on the trees in the fall and overwinter in this stage. The eggs hatch about the same time and the larvae of both species mature about the third week in June. They drop to the ground and form cocoons at a depth of about an inch. The adults emerge about the same time, commencing usually during the last week in October and continuing until early December or until the ground freezes.

The larvae resemble each other but they are easily separated by the presence of vestigial pro-legs on the fifth abdominal segment of the cankerworm (Hawboldt and Cuming 1950). The adult females are quite similar but the winter moth has prominent vestigial wing pads which are lacking on the cankerworm. The males can also be easily distinguished in the field; the cankerworm is greyish in colour with whitish markings on the wings, whereas the winter moth is brownish with darker markings. Both sexes of the cankerworm are larger than the corresponding sexes of the winter moth.

The association of these species has been reported previously (Hawboldt and Cuming 1950; Smith 1950; Morris and Reeks 1954). Morris and Reeks found the two species in the proportion of 92 per cent winter moth to 8 per cent cankerworm in the larval stage in a stand of young red oak near Bridgewater, Nova Scotia in 1952 and 1953. In the course of studies of control, samples of combined female populations were taken throughout the emergence period on red oak and maple shade trees banded with tanglefoot. Table 1 shows the totals and percentages for Bridgewater and Liverpool, Nova Scotia from 1950 to 1957. The proportions varied considerably from year to year but the winter moth was always more numerous than the cankerworm.

An interesting result of this close association is the habit of the winter moth of laying its eggs in the empty egg shells of the previous generation of the cankerworm (Fig. 1) (Smith 1953). The cankerworm lays all its eggs in large compact masses, sometimes encircling a twig or small branch, whereas the winter moth lays its eggs singly or in loose groups of 2 to 50 or more, under the bark scales, in crevices in the bark, and particularly under lichens on the trunks and branches of the trees (Fig. 2). When cankerworm egg shells are available they are used extensively for oviposition sites. Examination of small random samples of cankerworm egg shells gave some indication of the extent to which

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Figure 1.—Egg shells of *A. pometaria* showing eggs of *O. brumata* deposited in them. Photo by L. E. Williams.

Figure 2.—Eggs of *O. brumata* laid under lichen on *Quercus borealis*. Part of lichen removed. Photo by E. B. Bates.

Figure 3.—Egg shells of *M. disstria* showing eggs of *O. brumata* deposited in them. Photo by E. B. Bates.

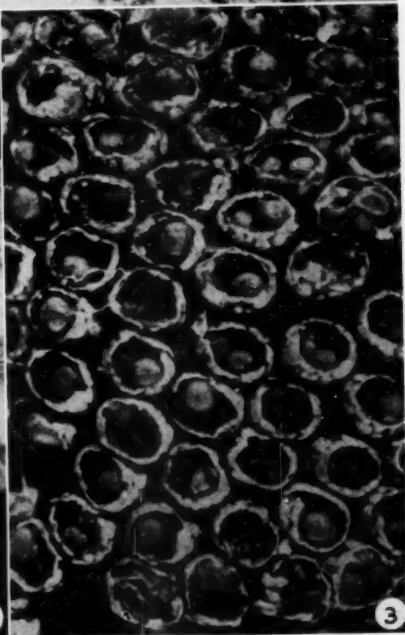
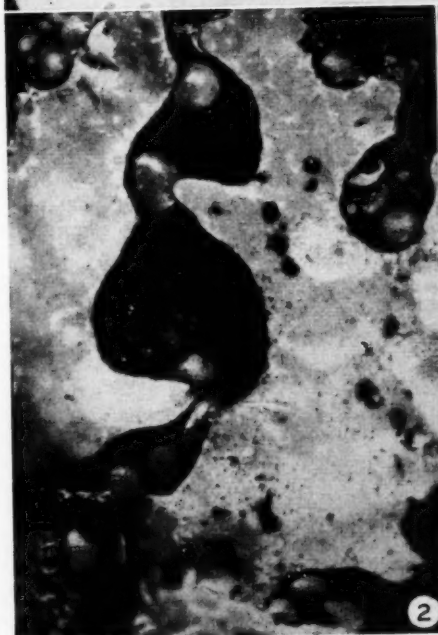
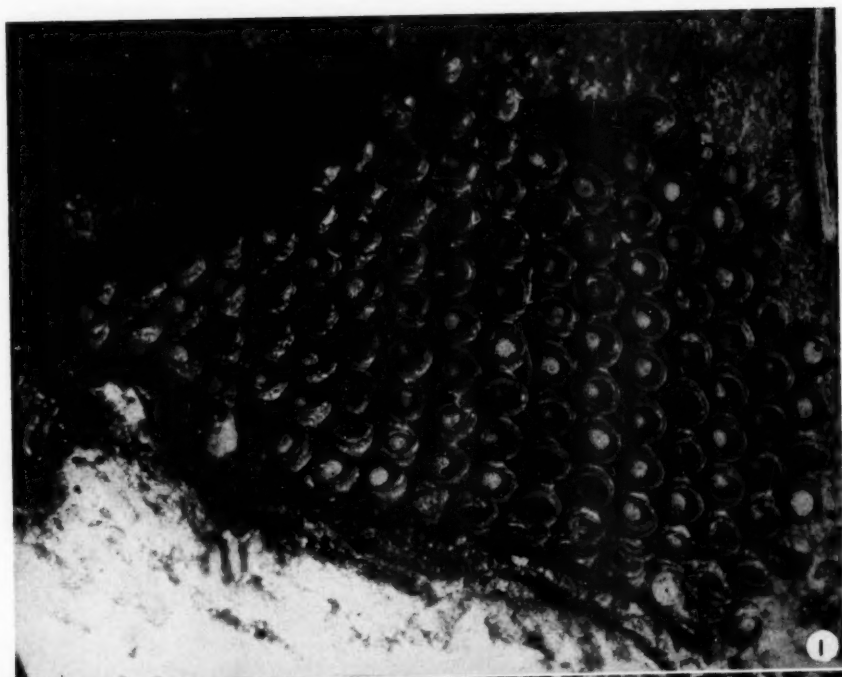


TABLE 1  
Percentage of Fall Cankerworm in Mixed Samples of Cankerworm  
and Winter Moth Females Taken on Banded Trees

Bridgewater			Liverpool	
Year	Total	% cankerworm	Total	% cankerworm
1950	1,566	1.4	not recorded	
1951	2,518	17.4	1,485	0.9
1952	4,803	3.4	1,569	0.5
1953	6,234	5.0	434	0.2
1954	8,714	7.7	not recorded	
1955	12,217	2.0	463	0.2
1956	14,149	1.2	606	1.7
1957	5,894	29.5	319	1.3

they are used by the winter moth. At Bridgewater, in 1952, 50 per cent of 737 shells and in 1955, 70 per cent of 614 shells were found to contain winter moth eggs. The winter moth also lays its eggs in the egg shells of two other native species: the forest tent caterpillar, *Malacosoma disstria* Hbn. (Fig. 3) and the eastern tent caterpillar, *M. americana* Fabr. Of a total of 1140 forest tent caterpillar egg shells in 5 masses examined in 1952, 74 per cent contained winter moth eggs. In 1955, 78 per cent of 284 shells examined had winter moth eggs in them. In some instances two eggs were deposited in a single cankerworm and as many as three were found in a single forest tent caterpillar shell.

The winter moth was apparently introduced to Nova Scotia from Europe within the last 40 to 50 years. Since the fall cankerworm does not occur in Europe this association is a recent development, peculiar to this continent. No reference has been found in the literature to the habit of using the egg shells of associated species. It obviously provides a convenient place for oviposition and good anchorage. It may also give some protection from weather.

Observations suggest that the close association of these similar species also results in some attempted cross-mating. On a number of occasions cankerworm males were observed apparently copulating with winter moth females. In two cases the pairs were removed from the tree by lifting the male with forceps. Both remained firmly attached and were placed in cages. One pair remained in the copulating position for 30 minutes and the female subsequently laid several eggs which hatched, but the resulting larvae died.

#### Acknowledgements

The author is indebted to Dr. R. E. Balch for suggestions in preparing the manuscript and to Mr. D. B. Marks for assistance with the field work.

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## The Maple Leaf Cutter, *Paraclemensia acerifoliella* (Fitch) (Lepidoptera: Incurvariidae), Descriptions of Stages<sup>1</sup>

By D. A. Ross<sup>2</sup>

### Introduction

The following is chiefly a description of taxonomically important features of all stages of *Paraclemensia acerifoliella* (Fitch). Heretofore the most detailed description of the stages of an incurvariid appeared in Jensen's (1932) paper on *Incurvaria koernerella* Zell.

### Classification and Synonymy

The maple leaf cutter, *Paraclemensia acerifoliella* (Fitch), belongs to the Incurvariidae, one of the most primitive families in the suborder Frenatae (suborder Monotrysia of Börner, 1939). Asa Fitch (1856) described this species and placed it in the genus *Ornix* in the family Tineidae. Clemens (1860) referred it to the genus *Incurvaria* with the remarks that "The wing structure departs from that of the genus [*Incurvaria*] . . . ."

Walsingham (1882), after studying Chambers' (1873) description of *Tinea iridella* from a single specimen from London, Ontario, states that "This is, without doubt, *I. acerifoliella* (Fitch), of which a single specimen is in the collection of the Peabody Academy of Sciences, Salem, Mass." A typographical error in Felt's bibliography (1912) reads *tiridella* in reference to Chambers' article. *Gracilaria acerifoliella* Chambers (1875) is a homonym and refers to a leaf-folding moth whose host is also maple.

Busck (1903) proposed the name *Brackenridgia* for the genus of which *acerifoliella* is monotype. On learning that the name *Brackenridgia* was pre-occupied in Crustacea, Busck (1904) substituted " . . . the new generic name *Paraclemensia*, thus retaining in the name the tribute to the founder of the study of Microlepidoptera in this country" [Brackenridge Clemens]. Dietz's (1905) revision contains a typographical error—*Brekenridgia*.

Fitch (1856) proposed the common name "maple leaf cutter" for this species and Herrick (1922) renamed it the "maple case bearer". Since the species is both a cutter and a case bearer, both names are suitable. However, the former has priority and has been approved by the American Association of Economic Entomologists (Muesebeck 1946).

### Descriptions of Stages

#### Adult

Fitch (1856) described the coloration of the adult as follows: "Their [forewing] fringe is black interspersed with scales of brilliant blue. On their under sides they are dusky with a grayish silvery luster and a pale purple reflection. The hind wings are pale smoky brown and translucent, with pale blue and purple reflections, and their fringe is pale brown. The head of the crown and between the antennae has a dense tuft of erect bright orange yellow hairs. The feelers [palpi] . . . of a gray color. The antennae are black brown . . . . The thorax is brilliant steel blue . . . . In common with the underside of the legs, it is dark brown with a strong satin-like lustre, the feet [tarsi] being whitish." Forbes (1923) referred to the underscaling as being "deep purple-blue densely over-laid with peacock green." This green coloration is apparent only under certain light conditions.

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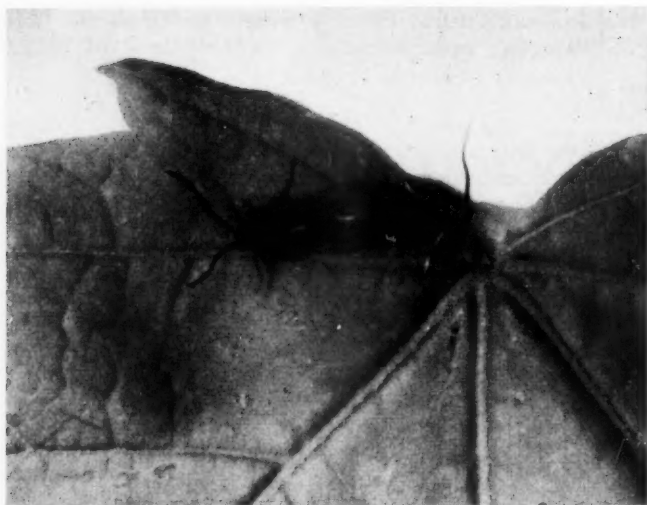


Fig. 1. Female (left) and male maple leaf cutter moths. Note sexual difference in relative position of curve in antenna.

The only thing the writer can add to the colour description is that the patch of orange-yellow hairs on the head extends caudad of the eyes over the postgenae and circumscribes the prothorax along its foremargin. There is a tuft of orange-yellow hairs on the anterior portion of the antennal scape. The moth ranges from 4.3 to 6.3 mm. in length; the wings from 8.5 to 13.0 mm. in expanse. A further description of some of the morphological features of taxonomic value follows.

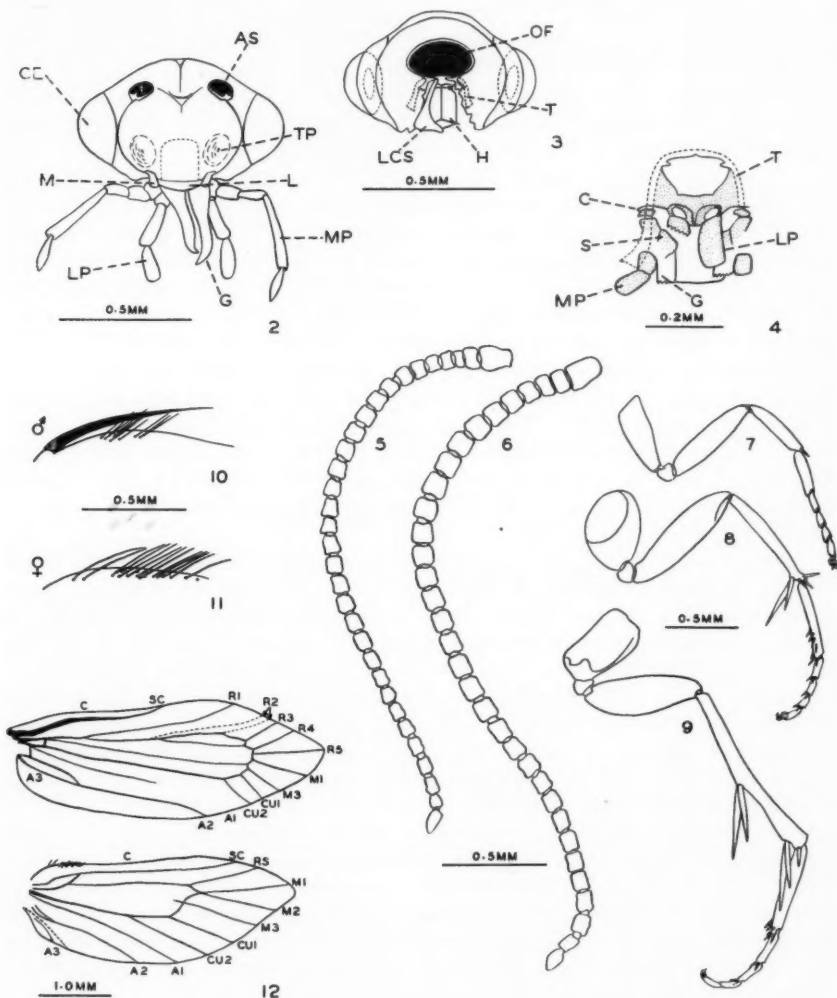
*Head:* the compound eye is hemispherical and relatively small, its diameter equal to about half the distance between the compound eyes (Figs. 2 and 3). Ocelli are absent. The antennae, longer and thicker in the male, are densely scaled (the scales in irregular rows), thread-like, with a characteristic bend in living specimens (Fig. 1). The bend is relatively nearer the tip in the female. The number of antennal segments is variable; 29 to 32 in females, 33 to 35 in males (Figs. 5 and 6). The differences in length and relative position of the bend of the antennae is useful in determining sex of adults in the field. The scape, roughly twice as long as the following segments, fits into a shallow depression posterior to the antennal socket.

The frontal tentorial pits (TP) are in a deep depression, farther dorsad than might be expected in such a primitive family. The depressions receive the maxillary palpi (MP) when they are folded against the cranium in the rest position.

The short labrum (L) is distinctly separated from the clypeus by the clypeo-labral suture. No pilifers were observed. The mandibles (M) are relatively large, but non-functional. The maxilla (Fig. 4) consists of a short, straight, membrane-like galea (G) or proboscis covered with small scattered setae, and a distinct triangular cardo (C) and a stipes (S) bearing the normally folded, five-segmented, maxillary palpus. Several prominent bristles are present near the distal tips of its third and fourth segments. When extended, the maxillary palpus is longer than the head. The labial palpus (LP) is large and 3-segmented, longer than the proboscis (Fig. 2).

*Thorax*: the only thoracic features generally considered to be of particular taxonomic importance in Lepidoptera are the appendages.

The epiphysis is absent from the fore tibia. Mid and hind tibiae each bear a pair of spurs near the tip, and a second pair just distad of the half-way point on the hind tibiae. Bristles are present on the tibia and tarsi (Figs. 7, 8, and 9) and there are numerous long hairs on the dorsal edge of the hind tibia. Tibial



Figs. 2 to 12. Adult *Paraclemensia acerifoliella* (Fitch), scales and hairs removed. 2 - cephalic aspect of head, 3 - caudal aspect of head, 4 - caudal aspect of mouthparts, 5 - antenna of female, 6 - antenna of male, 7 - foreleg, 8 - middle leg, 9 - hind leg, 10 - frenulum of male, 11 - frenulum of female, 12 - wings of female. AS - antennal socket, C - cardes, CE - compound eye, G - galea, H - hypopharynx, L - labrum, LCS - left cervical sclerite, LP - labial palpus, M - mandible, MP - maxillary palpus, OF - occipital foramen. S - stipes, T - tentorium, TP - tentorial pit.

hairs on the female are as long as the metatarsus, but on the males they are less than half as long.

The wings are fringed, broadly lanceolate, the hind wing the same width as the fore wing. Aculeae are present over the surface. The wing venation is shown in figure 12. The fore wing has 11 veins, all separate; vein *M2* is absent. The first anal is incomplete, and the third anal joins the second at a point one-third the length of the second anal vein. The position of *R2* varies as shown in the figure. Eight veins are present in the hind wing; *M1* and *M2* are short stalked, *M1* ending above and *M2* below the wing apex. The anal margin is folded under in the rest position. Wings of males are equipped with a long frenulum and a group of adjacent broad bristles on the costal margin (Fig. 10). The female has two long bristles and a group of slightly shorter ones somewhat distad of the first two (Fig. 11).

Fitch (1856) states that: "The mid vein forms a deep groove, lengthwise, from the base parallel with the inner margin almost to its tip, and on the middle of the wing towards its tip is another similar groove. The tips of the wings are commonly bent inwards, giving them when closed, the appearance of a little pod enveloping the abdomen". This curved condition of the wing tips is due to the presence of prominent grooves in the fore wing along each of the veins from *R4* to *M3* which permit a slight fan-like folding of the wing-tips.

*Abdomen:* in the male there are eight generalized abdominal segments, in the female seven. Each of these, excepting the first, has a definite broad sclerotized tergite and sternite. The first segment is largely membranous with a narrow, sclerotized band along the cephalic portion of the tergite and sternite. The tergal band is continuous with the tergo-pleural groove which passes obliquely cephalo-ventrad of the first spiracle to fuse with a small curved triangular pleural plate (Fig. 13).

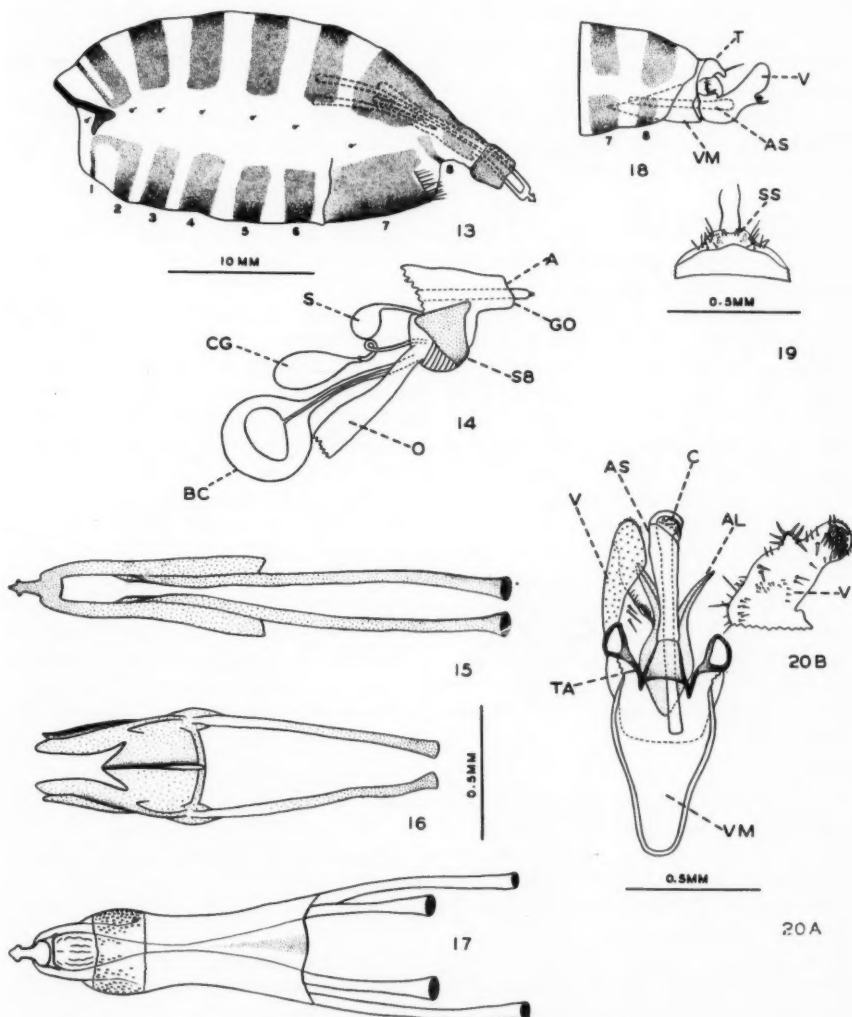
The seventh tergite and sternite of the female are very long, the latter bearing prominent setae on its caudal margin. The eighth segment is much reduced, with a narrow tergite. The sclerotized portion of the sternite is relatively broad laterally, narrowing ventrally. Segments nine and ten of the female are modified to form the genitalia. The "ovipositor" is supported by two pairs of long hollow rod-like apophyses which apparently are invaginations of the walls of the ninth and tenth segments. When retracted into the abdomen, the cephalic tips of the dorsal pair lie within segment five, the ventral pair within segment six. The ventral pair fuse at the caudal tip in the form of a U with a small faintly longitudinally grooved spearheaded piercer at the outer end of the U. Lateral flanges serve as muscle attachments (Fig. 15). The dorsal pair are joined by a dorsal plate with projections extending caudad. The lateral sides of these projections curve ventrad. A median flange extends ventrad from the main plate. This flange and the projections serve for muscle attachments (Fig. 16). Masses of protractor and extensor muscles extend to the four cephalic tips of the apophyses; each tip is capped with a large, transparent, membranous sphere.

Posterior to segment eight in the male is the dorsal tegumen fused to the ventral vinculum (Fig. 18). The scoop-shaped vinculum or saccus (VM) extends anteriorly into the seventh segment. Two rudimentary socii (SS) are borne at the tip of the tegumen (T); the uncus is absent (Fig. 19). The valva (V) is long and broad with the distal end rounded. A small projection on the inner margin bears six prominent marginal spines; slightly smaller spines occur

on the inner face near the tip. Numerous minute spines, the cornuti (C), are borne near the posterior tip of the aedoeagus (AS in Fig. 20A).

There are seven pairs of ovoid abdominal spiracles in both sexes.

This species has four pairs of ovarioles which end in a ventrally located



Figs. 13 to 20. Adult *Paraclemensia acerifoliella* (Fitch), scales and hairs removed. 13 — lateral aspect of abdomen and genitalia of female (flattened on microscope slide), 14 — diagram of female reproductive system, 15 — "ovipositor" and ventral apophyses, 16 — dorsal apophyses, 17 — female genitalia, 18 — abdominal segments and genitalia of male, lateral aspect, 19 — tegumen of male, 20A — male genitalia, dorsal aspect, left valva and tegumen removed, 20B — left valva, inner aspect. A — anus, AL — anellus lobe, AS — aedoeagus, BC — bursa copulatrix, C — cornuti, CG — cement gland, GO — genital opening, O — oviduct, S — spermatheca, SS — socius, S8 — sternite eight, T — tegumen, TA — transtilla, V — valva, VM — vinculum.

oviduct (Fig. 14). Dorsad of the oviduct is the large subspherical bursa copulatrix (BC) with its long straight duct leading to the vagina. No signa are present. An obovoid "cement reservoir" is also connected to the vagina by a long, once-looped duct. Part way between the loop and the base of the cement gland (CG) is a small expansion with a sclerotized semiannulus, possibly the location of a valve. The spermatheca (S), smaller than the "cement reservoir", is a simple ovoid organ with a straight duct. At least in some cases, the bursa copulatrix and spermatheca are located on the left side of the abdomen, the cement reservoir on the right side.

Richards (1933) proved that there is only one genital slit in the females of *Incurvaria russatella* Clemens. *Paraclemensia acerifoliella* apparently also has only one genital opening.

### Egg

The egg is ovoid, with a membranous, translucent, minutely reticulate chorion. The largest eggs taken from a 12-hour-old adult were 0.32 to 0.34 mm. long by 0.23 mm. wide.

Observations in the field indicate that swelling of the egg occurs during the incubation period. This is further substantiated by the following measurements: 1-hour-old eggs from three different females were 0.36 by 0.23 mm.; eggs with partially developed embryos ranged from 0.41 to 0.47 mm. in length by 0.28 to 0.37 mm. in width. J. J. deGryse (1928) recorded measurements for eggs 10 or more days old as 0.45 to 0.54 mm. in length by 0.33 to 0.49 mm. in width.

As the embryo develops between the leaf epidermises, the egg flattens slightly and becomes more circular in outline. For this reason Herrick (1922) gives three measurements for the maple leaf cutter egg: "... .45 mm. in length, .34 mm. in width and .24 mm. in thickness."

Just before hatching, the embryonic larva may be observed lying in the form of a U with its head and anal segment close together, invariably directed toward the opening in the egg pocket. When the chorion has broken, the larva moves into some other position, a useful fact for anyone attempting to determine the approximate time of hatching without the necessity of removing the leaf tissue.

### Larva

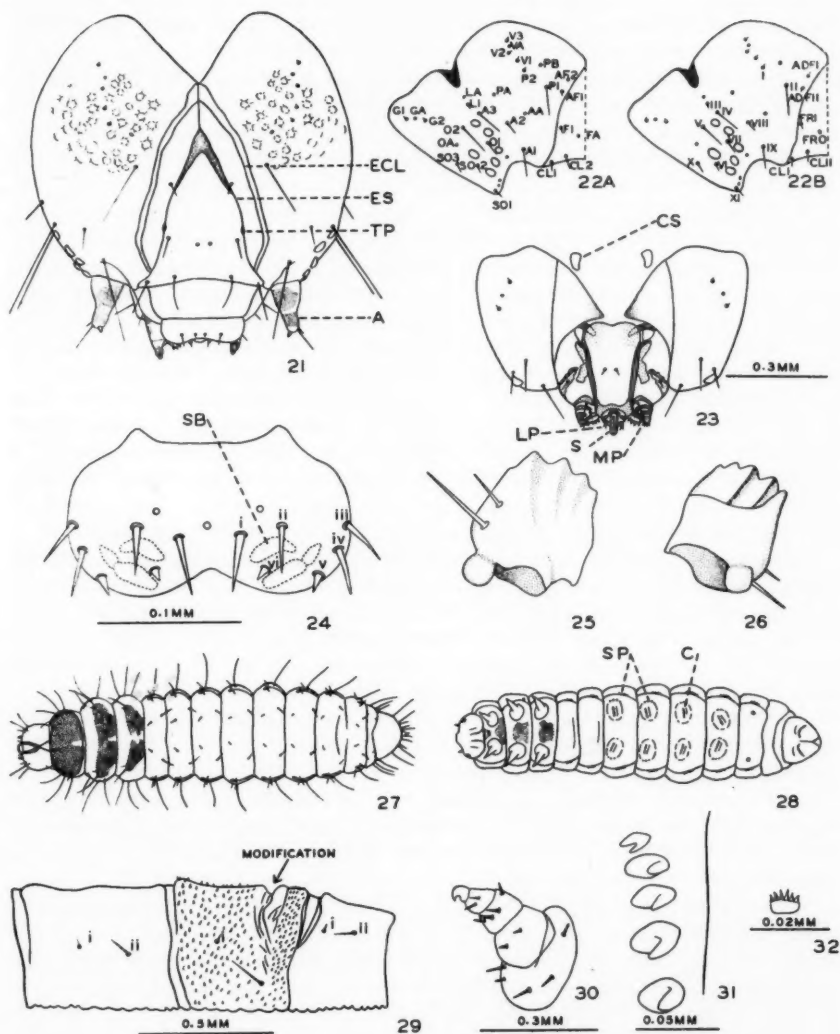
The following descriptions do not include the chaetotaxy, a subject which is discussed under a separate heading.

The larva usually moults five times. Head capsule measurements indicate that larvae in the third to sixth instars which fed on the thick "sun foliage" had wider head capsules than those that fed on the thin foliage produced under shaded conditions.

*First instar.* Length: 1.5 to 1.7 mm. The widest segment, the prothorax, is from 0.22 to 0.29 mm. in width; the body tapers from the first thoracic segment caudad to the anal plate which is about 0.1 mm. wide. The larva is slightly flattened and the pleural lobes project noticeably, apparently even more so than in the later instars. The head capsule ranged from 0.21 to 0.23 mm. across the widest portion.

The larva is a pale rusty brown, the body pigmentation being slightly darker than in later instars; the head is medium brown, darkest along the clypeo-labral sulcus and the caudal margin of the cranium, with a black blotch on the caudo-lateral margins of the cranium. The prothoracic tergite, anal plate, prothoracic sternellum and true legs are sclerotized, the same colour as the head.





Figs. 21 to 32. Larva, *Paraclemensia acerifoliella* (Fitch). 21 — dorsal aspect of head of ultimate instar, 22 — cranial setal map of first instar, distorted to show external aspects on one plane (22A — Hinton system, 22B — Dyar-Forbes system), 23 — head of ultimate instar, ventral aspect, 24 — labrum of ultimate instar, outer aspect, 25 — mandible of ultimate instar, anterior aspect, 26 — mandible of third instar, inner aspect, 27 — ultimate instar, feeding stage, dorsal aspect, 28 — ultimate instar, non-feeding stage (setae not shown), 29 — lateral aspect ultimate instar showing modification of segment seven, 30 — proleg, ultimate instar, 31 — crochets on A4 ultimate instar, 32 — one of anal forks, ultimate instar. A — antenna, C — crochets, CS — cervical sclerite, ECL — ecdysial cleavage line, ES — epistomal sulcus, LP — labial palpus, MP — maxillary palpus, S — spinneret, SB — sensory bud, SP — sclerotized patches, TP — tentorial pit.

The integument, excepting the conjunctival membranes and a patch on the tergite of abdominal segment seven, is minutely tuberculate, unlike the following instars, which are covered with minute spinules.

Two to four crochets are present on each member of the five pairs of poorly developed prolegs; the following formulae are examples of crochet distribution: 2, 3, 3, 3, 3; 2, 3, 4, 3, 3. About 8 to 15 scale-like anal combs with long teeth were indistinctly observed (oil immersion) about the anal aperture.

*Second instar.* Length, 2.2 to 2.9 mm.; head capsule width, 0.39 to 0.45 mm.; thoracic and abdominal segments one to seven are about the same width, thus there is no gradual taper as in the first instar. The mesothoracic and metathoracic tergites are sclerotized. Much of the integument is covered with minute spinules; the swelling on the seventh segment is smooth, the remainder is minutely tuberculate as in the first instar. The following are examples of crochet formulae: 5, 4, 6, 6, 6; 5, 4, 7, 7, 7; 4, 4, 7, 6, 8; 4, 6, 5, 6, 6.

*Third, fourth, and fifth instars.* No particularly distinctive characters were noted that might be used in separating these instars excepting possibly a few that will be mentioned in the description of the ultimate instar. Length as follows: third instar, 2.1 to 2.8 mm.; fourth instar, 2.7 to 3.5 mm.; fifth instar, 3.8 to 5.5 mm.

*Ultimate instar.* Length, 5.5 to 6.5 mm.

*Head:* head capsule width ranged from 0.64 to 0.84 mm.; almost prognathous, being directed downward only slightly; amber brown, with a small black patch at its lateral caudal margins, and another over each group of lower ocelli. The ocellar patch first appears in the third instar. There is a black A-shaped marking in the apex of the triangle formed by the lateral branches of the epistomal sulcus (Fig. 21). The upper cranium latero-caudad of setae *i* in the general area of Hinton's V series of setae is roughened by small irregular dome-like protuberances arranged in irregular rows (Fig. 21). This condition appears first in the third instar.

The ecdysial cleavage line (ECL) in the maple leaf cutter larva first appears distinctly in the fifth instar although it is not complete until the ultimate instar. Its lateral branches extend from the vertex to the epistomal sulcus (ES) a short distance dorsad of seta *Cl*.

The labrum (Fig. 24) has four pairs of long tactile setae, two pairs of short setae, at least three pairs of sensory buds (underside) and three punctures. The writer has not seen the median puncture illustrated for any other species of Lepidoptera. The distal end of the labrum in the final larval instar has a shallow notch; the relative depth of the notch having decreased from the first to the final instar. Numerous caudally directed spinules are present on that portion of the labrum directly caudad of the two central pairs of setae *i* and *ii*.

The mandibles (Figs. 25 and 26) are black tipped, and have five teeth, the fifth, the upper tooth, is much smaller than the others. In the first instar, the teeth are relatively longer than in the ultimate instar. The remaining mouthparts generally are not referred to taxonomically and in this case are not particularly different from the mouthparts of many other higher Lepidoptera, at least in gross structure.

The antenna has three sclerotized segments, the third minute. There is no sclerotized bridge across the membrane surrounding its base.

*Thorax:* the thoracic tergites have a characteristic sclerotized pattern (Figs. 27 and 28) which first appears distinctly in the penultimate instar. The

sternellum is distinct in the prothorax, less so in the other segments. The basisternum is also fairly definitely outlined on all three thoracic segments. A large pleural plate bearing one seta is present on each thoracic segment (seta *pi* on the prothorax and seta *vi* on the others). The prothorax bears a single pair of thoracic spiracles which are large and broadly oval with a sclerotized rim.

The legs on the prothorax are separated by a distance equal to about one half the width of the coxal cavity, the mesothoracic and metathoracic legs by more than the width of their coxae. Each leg has five sclerotized segments, ending in a single inwardly hooked claw. The second segment, the trochanter, is very small and is confined to the caudo-lateral margin of the coxa (Fig. 30).

**Abdomen:** there are no distinctive pigmented markings on the flesh-coloured abdomen and only a portion of the ultimate segment, the tenth tergite, is faintly sclerotized. In contrast, the genus *Incurvaria*, which is considered to be only slightly more primitive, has definite abdominal sclerites on the tergum and sternum. Some of the ultimate instar larvae show small sclerotized muscle attachments on the dorsum and venter (Fig. 28) of the abdomen. This condition was noticed only on larvae from overwintering cases.

The seventh tergite is modified in such a manner that a part of the integument near the caudal margin of the segment may be expanded with body fluid to produce a slight swelling. This modification may help to prevent loss of the larval case when the larva is crawling over the foliage; it may also function as an inner compass point during the case cutting process, thus ensuring a more or less regular symmetrical cut. This modified portion is naked (Fig. 29). The remainder of the integument is covered with minute spinules, the majority much less than 0.02 mm. in length. A few small areas are minutely tuberculate.

A group of 10 to 15 small anal forks or combs with 6 to 16 spinule-like teeth each, less than 0.002 mm. in length, are present dorsad of the anal aperture (Fig. 32).

The larva has five pairs of poorly developed prolegs on segments 3, 4, 5, 6, and 10 (Fig. 28). A uniordinal, uniserial row of crochets is present on the ridge anterior to the proleg fold, the points of the hooks projecting cephalad (Fig. 31). The number of crochets is variable, even in members of a pair of prolegs, as is illustrated by the following examples of crochet formulae from three ultimate-instar larvae: larva one, left side — 7, 6, 6, 6, 8; right side — 4, 6, 8, 7, 8: larva two, left side — 7, 6, 7, 5, 7; right side — 6, 6, 8, 7, 8: larva three, left side — 4, 7, 7, 6, 9; right side — 5, 8, 8, 7, 10.

There are eight pairs of broadly oval spiracles, those of segments seven and eight being larger than the others. Spiracle eight is sub-equal in size to the spiracle on the prothorax.

**Setae of the larvae:** the chaetotaxological nomenclature employed by Dyar and Forbes has been adopted for this paper for the following reasons: (1) it has priority, (2) it is adequate for most taxonomic purposes, and (3) it is fairly extensively used in classification of lepidopterous larvae. Fracker's system has been used for designating setae of the prothorax. An illustration showing the setal arrangement designated according to Hinton's system is also shown since references are made to his paper.

The chaetotaxy of the head of a first-instar larva is shown according to the system of Dyar and Forbes (Fig. 22B) and Hinton (Fig. 22A). It is very similar to the Adelidae illustrated by Hinton (1946) on page 7 of his paper, except that in *Paraclemensia* there is a puncture between the third and fourth

ocelli, and two of the four minute punctures he figures near seta SO1 (*xi*) were not observed by the present writer. Hinton presumes that the small setae on the retractable portion of the head are proprioceptors. *Paraclemensia* may retract its head slightly beyond the distal end of the stem of the epistomal sulcus which indicates that Hinton's V and G series of setae, P2 (*i*) and possibly A F 2 may function as proprioceptors. The cranial chaetotaxy of later instars appears to be similar to that of the first-instar larva.

The arrangement of setae on the prothorax is somewhat similar to that of *Adela cuprella* illustrated by Forbes (1923) on page 72 of his paper, except that there is one more seta in *Paraclemensia*. All of the tactile setae present in the ultimate instar (Fig. 34A) are also present in the first-instar larva. A small puncture is associated with setae *alpha* and *gamma*.

Seta *nu*, present in the later instars, is lacking in the first instar larva.

The normal number of "tactile setae" (*i* to *viii*) is present on the second- and ultimate-instar larvae on segments one to nine. Setae *vi* and *viii* are absent from the first-instar larva. In most cases the first six abdominal segments have three setae in the *vii* group although one (seta S V 3 of Hinton) may be lacking on segments one or two. One of the group is invariably absent from segments seven to nine. On the first-instar larva there is only one seta (S V 1 of Hinton) of group *vii* on the abdomen. Seta *iii a* is minute, about the size of the "proprioceptors", and in all segments is antero-dorsad from the spiracle. According to Hinton, it may function as a proprioceptor preventing the covering of the spiracle by the posterior margin of the preceding segment. Apparently it is absent from the first-instar larva.

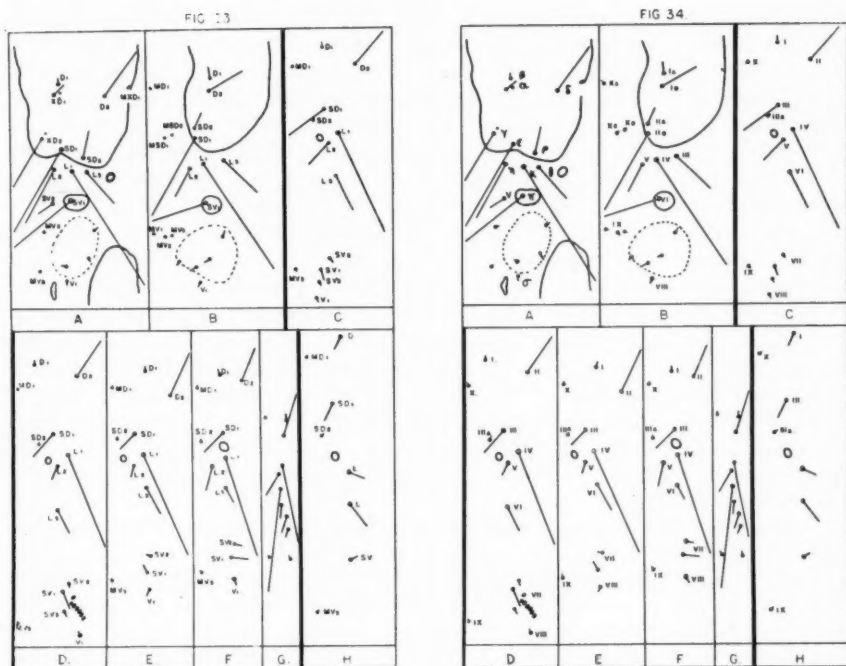
On the abdomen, seta *vi* is considerably ventrad of *v* and *iv*. It is longer than *v* excepting the setae on segments eight and nine. In prepared larval skins flattened on microscope slides, seta *iv* is slightly ventro-caudad of the spiracles on abdominal segments one to seven but in living individuals it is slightly dorso-caudad as shown in the setal map. It is definitely ventrad of the spiracle on segment eight. Seta *ii* on the seventh abdominal segment has been slightly displaced by the modification (Fig. 29) on the dorsum.

Hinton (1946) states that the "microscopic setae" are primary and that they are present at least on the first instars of such forms as Psychidae, Cossidae, Sesiidae, etc. In referring to the distribution of microscopic setae in the leaf miner *Eriocrania* he presumes that they are also present in the first instar. The present writer examined several first-instar *Paraclemensia* larval skins under the oil immersion lens but was unable to locate any "proprioceptors", although they were seen readily on second-instar larvae.

A microscopic seta (MXD1 of Hinton) is on the sclerotized portion of the prothoracic tergite; in the second instar it is immediately caudad. Two other mid ventral setae (MV2 and MV3) undesignated by Fracker are probably homologous with the *ix* setae of the mesothorax. Setae *x a*, *x c*, and *x d* (MD1, MSD1 and MSD2) and *ix* (MV1, MV2 and MV3) are present on both segments. Setae *ix* (MV3) and *x* (MD1) are present on the first nine abdominal segments.

### Pupa

In the autumn the pupae (in overwintering cases on the ground) are a transparent pale amber colour which makes it possible to observe developmental changes under transmitted light. When the preimaginal stage is attained, a few days before the pupa emerges from the cocoon, only the external features of the preimaginal such as the scales are discernible. The pupa is incomplete: the



Figs. 33 and 34. Setal maps of *Paraclemensia acerifoliella* (Fitch). A to G — ultimate instar larva, prothorax, mesothorax, and abdominal segments 1, 6, 7, 8, 9, (C to G); H — pupa — abdominal segment 6. Fig. 33 according to Hinton, Fig. 34 Dyar and Forbes, classification of setae.

appendages of the head are free and the only fusion in the thoracic appendages occurs between the inner margins of the wings.

Pupae range from 4.2 to 5.7 mm. in length and from 1.2 to 1.5 mm. in width. Generally the females are larger than the males.

**Head:** the epicranial suture of Mosher (1916), an inverted Y, is on the dorsum of the head (Fig. 37). This "suture" is homologous to the ecdysial cleavage line on the larva. Its stem is continuous through the prothorax to the caudal margin of the metathorax. Just before adult emergence, the pupal case splits transversely along the two lateral branches from antenna to antenna, caudad along the stem to the hind margin of the metathorax. The epistomal sulcus has disappeared, excepting that short portion extending from the tentorial pits to the labrum. Two long setae, probably seta *ii* of the larvae, arise from the anterior tip of the pupa. Four smaller setae, presumably the clypeal setae of the larvae, arise about half way between the slit-like tentorial pits and the distal tip of the labrum. These latter setae are about half the length of those situated at the tip of the head.

The fairly prominent mandibles are non-functional in the pupa. They are free along their distal and lateral margins, indistinctly blending into the cranium at the base. The maxillary palpi appear immediately caudad of the glazed eyes, and curve ventrad over the first legs to the edge of the maxillae.



The maxillae are short and lie laterad of the appendage composed of the labium and its two palpi. The labium plus its palpi are the same length as the maxillae.

The antennae extend laterad curving to the ventral side of the body laterad of the hind legs. The difference in antennal lengths between the sexes is a character that is extremely useful in determining the sex of pupae when only a hand lens is available. In the males, the antennae extend beyond the wing tips, almost to the tips of the hind legs. In the females, the antennae are much shorter than the wings, and extend only to the tips of the middle legs.

*Thorax:* the prothorax is relatively short; its anterior and posterior margins are almost parallel. The mesothorax is large and well developed, almost twice the length of the metathorax. Four setae (probably *i* and *iii*) are situated on the tergites of the meso- and metathorax; no setae are present on the prothorax.

The wings extend laterad, curve ventrally and lie against the abdomen, the mesothoracic wings covering the metathoracic wings, except for a narrow portion along their dorsal margins. The legs are folded against the thorax in such a manner that the coxae, tibiae and tarsi of the first two pairs of legs, the tarsi and distal portion of the tibia of the hind legs are partially exposed. The large broadly oval prothoracic spiracle is concealed by the lateral edge of the pronotum and the antenna.

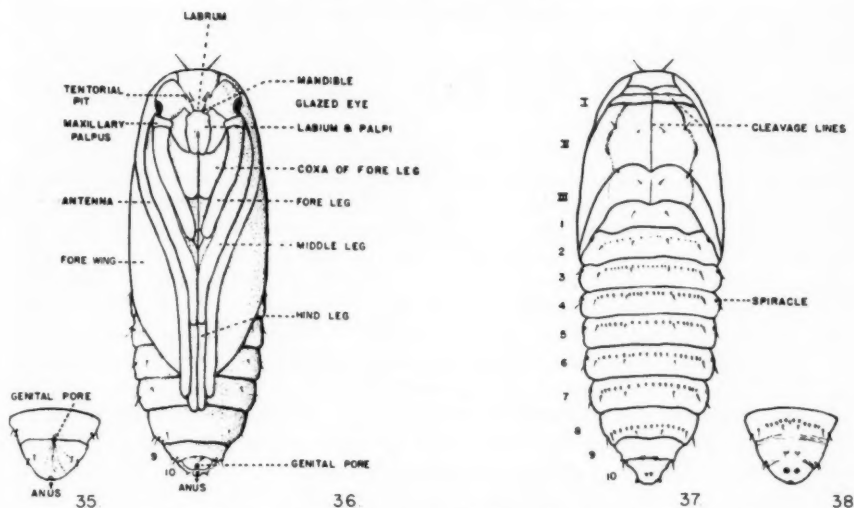
*Abdomen:* the abdomen consists of 10 segments, of which the terminal three are more or less fused and incapable of independent movement. Spiracles are present on the first eight segments, the first two on the membranous portion. The first spiracle is covered by the wings. Spiracles seven and eight have no apparent openings although spiracle seven is supplied with tracheae. Spiracle eight is vestigial, and non-functional. It is entirely absent in some females.

Sternite nine is produced caudad in the male, the extension being marked off by a sulcus (Fig. 36). The large oval genital opening appears at the end of a notch in the caudal margin of this sclerite, with a slight swelling on either side of the aperture.

In the female pupa, a genital slit with darkly sclerotized margins opens ventrally at the fore margin of segment nine (Fig. 35). There is a slight groove or wrinkle at the posterior margin of segment eight but there is no genital opening as there is in the higher Lepidoptera. Proleg crochet scars are faintly discernible on segments four to six. A single row of caudally directed spines is present on each of tergites two to eight. The row on segment two is composed of very small, irregularly spaced, poorly formed spines. The others have large spines (the largest are approximately 0.02 mm. long), about 16 to 24 on tergites three to seven and 12 or 13 on tergite eight. The spines on segments two to seven are on the cephalic half of the tergum; those on segment eight are mid-way between the anterior and posterior margins. Four spine-like tubercles on the penultimate tergite have greatly enlarged bases on which are located the four setae of the segment. Tergite ten has two very prominent spine-like tubercles close together in the middle of the segment. Two extra tubercles are found in the males in a laterad position near the tip of the abdomen.

A few abdominal setae have been lost in transition; however the arrangement of those present is very similar to the corresponding setae on the ultimate-instar larva. Homologies have been determined entirely by size and relative position of the setae on the segment.

Segment ten bears no setae and the following refers to abdominal segments one to nine: seta *i* is present on each segment. A few pupal skins apparently showed scars of seta *ii*. Seta *iii* and three other setae probably *iv*, *v*, and *vi* are



Figs. 35 to 38. Pupa of *Paraclemensia acerifoliella* (Fitch). Fig. 35 ventral aspect of posterior tip of female, Fig. 36 ventral aspect of male, Fig. 37 dorsal aspect of male, Fig. 38 dorsal aspect of posterior tip of female.

also present. It may be noted in the larva that seta *viii* is always ventrad of microscopic seta *ix*. Therefore we may reasonably assume that seta *viii* is missing since there is no seta ventrad of that "proprioceptor" on the pupa (Fig. 34 H). Seta *iii a* is also present anterodorsad of spiracles two to eight and directly anterior to spiracle one. Seta *x* is present on segments three to eight. Seta *ix* is at the anterior margins of segments two to eight.

#### Summary

Features of all stages of *Paraclemensia acerifoliella* (Fitch) considered to be of particular taxonomic value are described in this paper. Only the more salient ones are summarized here.

The moth's antennae are long, have a variable number of segments — more in the male than in the female. The labrum is distinct as are the non-functional mandibles. The maxillary palpi are longer than the head; the three-segmented labial palps are well developed, and are longer than the proboscis. Epiphyses are lacking on the fore tibiae. The forewing has 11 veins, the hind wing 8. Grooves along veins R4 to M3 allow a slight fan-like folding of the tips. The "ovipositor" is spear-like, and is supported on two hollow rod-like apophyses; an opposing pair of apophyses joined by a plate lie above. Only one genital opening is apparent in the female. The uncus is lacking on the male genitalia; socii are rudimentary.

Egg measurements indicate that swelling of the egg occurs during embryonic development.

In the first instar, the mining stage, larvae are flattened; the body tapers from the widest segment, the prothorax, to the anal segment. In later case-bearing instars, the shape is more cylindrical. The integument of the first-instar larva is minutely tuberculate; later instars are covered with spinules. A number of scale-like anal combs are present on all instars. The ecdysial cleavage line

first appears distinctly in the penultimate instar, although it is not complete until the ultimate instar.

A median puncture, as well as the usual laterals, was observed on the labrum of the ultimate instar larva, possibly a further indication of the primitive position of this species.

Unlike *Incurvaria* there is little sclerotization of the larval tergum and sternum of the abdomen, even of the late instars. The seventh tergite is modified and the posterior part is inflated slightly; this portion is naked of spinules. Crochet formulae are so variable that they are of little use in separating instars. Setal maps of the head and body of the larva were prepared; the chaetotaxy is not considered to be unusual. Some authors have supposed that the microscopic setae *ix* and *x* are present on the first instar as well as the later instars, but the present writer was unable to find them on first-instar larvae.

The pupa is "incomplete", has vestiges of mandibles, prominent maxillary and labial palpi. A cleavage line completely transects the three thoracic tergites and branches once on the vertex of the head. In the males, the antennae extend beyond the wing-tips; in the females the antennae are shorter than the wings. A single row of spines is present on each of the tergites of abdominal segments 2 to 10. Possibly for the first time, the microscopic setae *ix* and *x* have been observed on the pupal abdomen. Spiracle eight, functional in the larva, is non-functional in the pupa and absent in some females. It is entirely lost in the adults.

#### Acknowledgments

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### **Tetrahydrofuran and its Use in Insect Histology**

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Tetrahydrofuran (tetramethylene oxide) has been recommended as a histological dehydrating and clearing agent for use in human pathology by Dahme and Rothmund (1) and more recently by Haust (2). Dahme and Rothmund recommended its use after a search for a non-toxic reagent miscible with both water and molten paraffin wax. These authors state that the toxicity of tetrahydrofuran only approaches that of ethyl ether, whereas dioxane, with similar properties, is highly toxic. Tetrahydrofuran would appear to be as safe for routine laboratory use as toluene and xylene when similar precautions are observed. Haust (1958) gives various schedules for its use on human pathological material, and compares it with the more traditional methods. She concludes that it is simpler to use, and at least equally as efficient as the conventional dehydrating and clearing agents. In our work on insects we have extended its use to a solute for fixing solutions, and for dissolving celloidin in a double embedding technique.

Its usefulness as a histological reagent is due to its particular physical properties. It is miscible in all proportions with water, ethyl alcohol (including other lower alcohols), chloroform, xylene, toluene, clove oil and cedar wood oil. In addition, it is perfectly miscible in all proportions with molten paraffin wax. This means that material can be placed in several changes of tetrahydrofuran and then placed in molten paraffin wax in an oven for embedding. Because of its lower boiling point (65°C) it easily evaporates from the paraffin in the embedding oven. Mercuric chloride, iodine and picric acid are soluble in this reagent. We have also found it to be an excellent solvent for celloidin or parlloidin. One slight disadvantage with tetrahydrofuran is its tendency to form peroxides, which are straw coloured at first, changing eventually to a darker brown. They do not appear, however, to affect its use in histology and can in any case be kept to a minimum by storing mixtures and solutions in a cold room or refrigerator at above 5°C. If the pure reagent is kept in amber bottles it does not form peroxides even when stored for fairly long periods; the recent addition of hydroquinone by the manufacturer (Eastman Kodak) retards the formation of the peroxides.

#### **Methods**

Tetrahydrofuran, in comparison to alcohols, does not have the same tendency to harden insect material, and, in our work, it has been used as a basis

for fixatives as well as for the dehydrating and "clearing" procedures. Paraffin embedded specimens prepared by the following methods have proved to be easier to cut than when traditional methods are used.

*Fixatives:*

- (1) Tetrahydrofuran — Carnoy.  
60 ml. tetrahydrofuran  
30 ml. chloroform  
10 ml. glacial acetic acid
- (2) Tetrahydrofuran — sublimate.  
95 ml. tetrahydrofuran  
8 g. mercuric chloride  
5 ml. glacial acetic acid
- (3) Tetrahydrofuran — Eltringham.  
145 ml. distilled water.  
100 ml. tetrahydrofuran  
10 ml. glacial acetic acid  
10 g. mercuric chloride

Of the above No. 3 gives precise nuclear staining and a minimum of hardening.

*Dehydrating and embedding procedures:*

From the above fixatives, or from other fixatives, the material can be placed directly in pure tetrahydrofuran. If a fixative containing water (as in No. 3 above), has been employed, the specimen should go into a mixture of equal parts of water and tetrahydrofuran for about an hour before the pure reagent. The schedule given below has been found to be adequate for insect material up to 4 x 4 x 2 mms. when specimens were dissected to allow penetration of fluids. These times can be extended for larger specimens.

1. Tetrahydrofuran — 2 hrs.
2. Fresh tetrahydrofuran — 1 hr.
3. Tetrahydrofuran — molten paraffin, equal parts in sealed screw-topped jar in paraffin oven —  $\frac{1}{2}$  hr.
4. Molten paraffin — 1 hr. (open container).
5. Molten paraffin fresh change —  $\frac{1}{2}$  hr.
6. Specimen "blocked".

*Double embedding:*

This schedule is based on the methods of Espinasse and Peterfi as given in *The Microtometist's Formulary and Guide* (3), with the difference that tetrahydrofuran is the solvent used throughout.

1. From fixative place in tetrahydrofuran for 2 hours.
2. Fresh tetrahydrofuran — 1 hr.
3. 1% parlodin in tetrahydrofuran — 12-24 hrs.
4. 2% parlodin in tetrahydrofuran — 24-48 hrs.
5. Rinse quickly for a few minutes in tetrahydrofuran.
6. Place in molten paraffin wax in embedding oven, 2 changes of 1 hour each.
7. Block.

The above technique is useful for insects with hard cuticles; it is sometimes advantageous to include 10% beeswax in the final embedding wax.

**Summary**

The use of tetrahydrofuran as an histological reagent is still in the experimental stage when compared with the long established common dehydrating



and clearing media. However, from our experience, which includes its use on mammalian tissues as well as insect material, we find that it causes less hardening than conventional reagents. Moreover, it is convenient that only one reagent is required for both dehydrating and clearing. Shrinkage and disturbance of tissues as noted in the finally stained sections is less apparent than with other methods, and the staining of various cytological elements is very precise after its use. It has been found that blocks prepared by this reagent are more easily sectioned. In addition, the saving of time in preparing specimens can be a great advantage.

Tetrahydrofuran can be obtained from the usual laboratory suppliers and is manufactured by Eastman Kodak Company.

#### Acknowledgment

Acknowledgment is made to Dr. W. F. Baldwin for his advice, and encouragement of this work.

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### Notes on Parasites of Diprionidae in Europe and Japan and Their Establishment in Canada on *Diprion hercyniae* (Htg.) (Hymenoptera: Diprionidae)<sup>1</sup>

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Approximately 32 million cocoons of 11 species of spruce- and pine-feeding sawflies were collected in Europe and Japan from 1933 to 1940 and sent to the Belleville laboratory for rearing parasites for release in Canada against the European spruce sawfly, *Diprion hercyniae* (Htg.). Over half a million of the cocoons were *Diprion polytomum* (Htg.) and the parasites that emerged from these were discussed in previous papers (Finlayson and Reeks, 1936; Finlayson and Finlayson, in preparation). In addition to cocoons, almost half a million eggs of *Neodiprion sertifer* (Geoff.) were collected in Europe and reared to obtain egg parasites.

#### Collection and Rearing

The sawfly cocoons collected were of *Diprion frutetorum* (F.), *D. pallidus* (Klug), *D. pini* (L.), *D. virens* (Klug), *N. sertifer*, *Lygaeonematus abietinus* (Chr.), and *Pachynematus scutellatus* (Htg.), from Czechoslovakia; *N. sertifer*, from Esthonia, Hungary, and Sweden; *D. pini*, from Germany and Holland; *D. abieticola* (Dalla Torre), from Romania; *D. similis* (Htg.), from Poland; and *D. nipponicus* Roh. and *N. sertifer*, from Japan. No parasites were reared from *D. abieticola*. The *N. sertifer* eggs were collected on needles of *Pinus sylvestris*

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TABLE I  
Percentages of cocoons of *Diprion frutetorum*, *D. nipponicus*, *D. pallidus*, and *D. pini* from which various parasites emerged according to countries and years of collection

<i>D. frutetorum</i> From 1,980 cocoons collected in Czechoslovakia in 1933 and 1934		<i>D. nipponicus</i> From 257,261 cocoons collected in Japan in 1935, 1935, and 1937		<i>D. pallidus</i> From 3,010 cocoons collected in Czechoslovakia in 1936	
<i>Aptesis basizonia</i> (Grav.).....	20.5	<i>Drino gilva aurora</i> Mesn.....	2.44	<i>Hypsantyx impressus</i> (Grav.).....	5.9
<i>Hemiteles inimicus</i> Grav.....	2.7	<i>Lamachus albopictus</i> Cush.....	0.86	Tachinid sp.....	3.4
<i>Exenterus</i> sp.....	0.6	<i>Exenterus adpersus</i> Htg.....	0.13	<i>Holocremnus clandestinus</i> (Holmg.).....	0.8
<i>Dibrachys cavaus</i> (Wlkr.).....	0.5	<i>Monodontomerus japonicus</i> Ashm.....	0.02	<i>Holocremnus ratzeburgi</i> (Tschek).....	0.3
<i>Amblymerus subfumatus</i> (Ratz.).....	0.5	<i>Lophyproctus</i> sp.....	0.01	<i>Apopsis</i> sp.....	0.2
<i>Hemiteles areator</i> Panz.....	0.4			<i>Exenterus amictorius</i> (Panz.).....	0.2
Tachinid spp.....	0.4			<i>Rhorus</i> ( <i>Cyphanga</i> ) sp.....	0.2
<i>Monodontomerus dentipes</i> (Dalm.).....	0.3			<i>Gelis</i> spp.....	0.2
<i>Lamachus intermedius</i> (Ratz.).....	0.3			<i>Amblymerus subfumatus</i> (Ratz.).....	0.1
<i>Holocremnus ratzeburgi</i> (Tschek).....	0.2			<i>Apopsis basizonia</i> (Grav.).....	0.1
<i>Pimpla alternans kolthoffi</i> Aur.....	0.2			<i>Lamachus marginatus</i> (Brischke).....	0.1
<i>Lamachus egues</i> (Htg.).....	0.2				
<i>Dahlbominus fuscipennis</i> (Zett.).....	0.1				
From 831 cocoons collected in Germany in 1934		<i>D. pini</i> From 5,167 cocoons collected in Holland in 1936		From 725 cocoons collected in Czechoslovakia in 1936	
<i>Lamachus marginatus</i> (Brischke).....	1.1	<i>Diplostichus janithrix</i> (Htg.).....	1.5	<i>Lamachus</i> sp.....	0.4
<i>Holocremnus clandestinus</i> (Holmg.).....	0.5	<i>Aptesis basizonia</i> (Grav.).....	0.4	<i>Diplostichus janithrix</i> (Htg.).....	0.4
<i>Aptesis basizonia</i> (Grav.).....	0.2	<i>Dahlbominus fuscipennis</i> (Zett.).....	0.3	<i>Exenterus</i> sp.....	0.2
		<i>Agrothereutes nubeculatus</i> (Grav.).....	0.1	<i>Holocremnus clandestinus</i> (Holmg.).....	0.2

TABLE II

Percentages of cocoons of *Diprion similis*, *D. virens*, *Lygaconematus abietinus*, and *Pachynematus scutellatus* from which various parasites emerged according to country and year of collection

<i>D. similis</i> From 4,051,400 cocoons collected in Poland in 1937		<i>L. abietinus</i> From 3,803 cocoons collected in Czechoslovakia in 1937	
<i>Aptesis subguttatus</i> (Grav.)	1.585	<i>Rhorus</i> ( <i>Cyphanza</i> ) sp. nr. <i>lapponicus</i> Rom.	0.2
<i>Exenterus amictorius</i> (Panz.)	0.125	<i>Mesoleius</i> sp.	0.2
<i>Aptesis basizonia</i> (Grav.)	0.101	<i>Lamachus marginatus</i> (Brischke)	0.1
<i>Drino inconspicua</i> (Meig.)	0.041	<i>Holocreminus ratzeburgi</i> (Tschek)	0.1
<i>Exenterus adspersus</i> Htg.	0.035	<i>Exenterus confusus</i> Kerr.	0.1
<i>Hypsantyx impressus</i> (Grav.)	0.007	<i>Erromenus</i> sp.	0.1
<i>Enicospilus</i> spp.	0.002	<i>Hypamblys</i> sp.	0.1
<i>Diplosichus janithrix</i> (Htg.)	0.002	<i>Cteniscus</i> sp.	0.1
<i>Olesicampe</i> spp.	0.002		
<i>Pelecystoma luteum</i> (Nees)	0.002	<i>P. scutellatus</i> From 1,847 cocoons collected in Czechoslovakia in 1937	
<i>Euryproctine</i> sp. nr. <i>Zemiophorus</i>	0.001		
<i>Bathythrix</i> sp.	0.001	<i>Rhorus</i> ( <i>Cyphanza</i> ) sp. nr. <i>lapponicus</i> Rom.	0.8
<i>Agrothereutes nubeculatus</i> (Grav.)	0.001	<i>Hypamblys</i> spp.	0.2
<i>Aspilota</i> sp.	0.001	<i>Trematopygus</i> sp.	0.1
<i>Monodontomerus dentipes</i> (Dalm.)	Numerous	<i>Erromenus</i> sp.	0.1
		<i>Mesoleius</i> sp.	0.1
<i>D. virens</i> From 883 cocoons collected in Czechoslovakia in 1933 and 1934			
<i>Lamachus intermedius</i> Htg.	1.6		
<i>Exenterus</i> sp.	0.8		
<i>Lamachus marginatus</i> (Brischke)	0.6		
<i>Tachinid</i> sp.	0.1		

*L.* in Sweden and Czechoslovakia, and of *Pinus nigra austriaca* (Hoess) Aschers. and Graebn. in Hungary.

Cocoons of *D. nipponicus*, *D. similis*, and *N. sertifer* (except all those from Esthonia and part of those from Japan) were reared in bulk by placing batches of approximately 25,000 cocoons on open, screen-bottomed trays. The trays were stacked one on top of another, with several inches between them to enable the emerged insects to escape. All cocoons were held at about 0°C. until a week before incubation, when the temperature was raised to 5°C. The rearing rooms were kept at a temperature of 22°C. and a relative humidity of 80 per cent. The insects emerged directly into quarantine rooms (one host species to each room), where both sawflies and parasites were collected daily with power suction equipment and venturi designed especially for the purpose. Sawflies were collected directly into jars of alcohol. The more abundant species of parasites were collected into large cages each of which held 500 to 800 specimens of one species. The parasite species that occurred in small numbers were collected directly into large vials. About 31,300,000 host cocoons were incubated by this bulk method. The number of hosts parasitized by gregarious chalcids could not be determined because they were not isolated for separate emergences. It is also possible that some re-parasitism of the hosts by these chalcids took place during the rearings.

The remainder of the host cocoons (about 84,000) were reared in individual cotton-stoppered vials, as described by Finlayson and Finlayson (in preparation).

The pine needles on which eggs of *N. sertifer* had been deposited were removed from the branches and placed on moistened blotting paper in petri dishes, where the parasites emerged.

TABLE III  
Percentages of cocoons of *Neodiprion sertifer* from which various parasites emerged according to countries and years of collection

From 32,600 cocoons collected in Estonia in 1939	From 24,901,500 cocoons collected in Hungary in 1934, 1935, and 1936, and 1,452,750 cocoons collected in Czechoslovakia in 1934 and 1935
<i>Exenterus abruptorius</i> (Thunb.).....24.7	<i>Exenterus abruptorius</i> (Thunb.).....5.5100
<i>Aptesis basizonia</i> (Grav.).....8.8	<i>Aptesis basizonia</i> (Grav.).....0.3890
<i>Exenterus amictorius</i> (Panz.).....4.4	<i>Lophyproctus luteator</i> (Thunb.).....0.2114
<i>Lamachus eques</i> (Htg.).....1.6	<i>Lamachus eques</i> (Htg.).....0.0523
<i>Lophyproctus luteator</i> (Thunb.).....1.0	<i>Drino inconspicua</i> (Meig.).....0.0112
<i>Exenterus adspersus</i> Htg.....0.2	<i>Exenterus amictorius</i> (Panz.).....0.0084
	<i>Thyridanthrax</i> sp.....0.0036
From 634,000 cocoons collected in Sweden in 1935	<i>Agrothereutes</i> sp.....0.0017
	<i>Mastrus</i> spp.....0.0010
* <i>Exenterus</i> spp.....5.10	<i>Agrothereutes nubeculatus</i> (Grav.).....0.0002
<i>Aptesis basizonia</i> (Grav.).....4.73	<i>Exenterus oriolus</i> Htg.....0.0001
<i>Lamachus eques</i> (Htg.).....0.08	<i>Dahlbominus fuscipennis</i> (Zett.).....Numerous
<i>Lophyproctus luteator</i> (Thunb.).....0.03	
	From 33,000 cocoons collected in Japan in 1936 and 1938
	<i>Lophyproctus</i> sp.....3.1
	<i>Drino</i> sp.....1.2
	<i>Exenterus adspersus</i> Htg.....0.1
	<i>Exenterus abruptorius</i> (Thunb.).....0.1

\*Mainly *E. abruptorius*, but a few *E. adspersus* present.

### Parasitism

Two species of hymenopterous egg parasites were identified from material collected in Europe. Seventy-nine species of larval and cocoon parasites (including hyperparasites) were identified from Europe. Of these, 40 were identified to species, two to variety and 37 to genus only. Of the parasites reared from the two species of sawflies imported from Japan, five were identified to species, one to variety, and nine to genus only. All hosts reared together were considered to be of one species but it is possible that a few cocoons of other species may have been present. Consequently, parasites that occurred in small numbers may have come from other hosts. Only the species occurring in comparative abundance are listed in the tables. Detailed data are on file at the Belleville laboratory.

The relative incidence of parasitism of each host species by different species in different areas is given in Tables I to IV. Parasites emerged in several successive years of rearing from some of the hosts. *Exenterus abruptorius* (Thunb.) and *Lophyproctus luteator* (Thunb.) were reared from *N. sertifer* for six years after collection.

TABLE IV  
Percentages of eggs of *Neodiprion sertifer* from which parasites emerged according to country and years of collection

From 239,000 eggs collected in Czechoslovakia in 1935	From 220,000 eggs collected in Sweden in 1935 and 1936	From 30,000 eggs collected in Hungary in 1936
<i>Achrysocharella ruforum</i> (Krausse).....2.07	<i>Tetracampe diprioni</i> Ferr.....9.82	<i>Tetracampe diprioni</i> Ferr.....0.63
<i>Tetracampe diprioni</i> Ferr.....0.02	<i>Achrysocharella ruforum</i> (Krausse).....0.85	<i>Achrysocharella ruforum</i> (Krausse).....0.01

## Establishment of Parasites

Thirty species of parasites from host material (including *D. polytomum*) collected in Europe and Japan were released in Eastern Canada. Those from Europe were: the egg parasites *Achrysocharella ruforum* (Krausse) and *Tetracampe diprioni* Ferr. (Hymenoptera); and the larval and cocoon parasites *Agrothereutes abbreviator* (F.), *Amblymerus subfumatus* (Ratz.), *Aptesis basizonia* (Grav.), *A. indistincta* (Prov.), *A. subguttatus* (Grav.), *Dahlbominus fuscipennis* (Zett.), *Exenterus abruptorius*, *E. amictorius* (Panz.), *E. confusus* Kerr., *E. tricolor* Rom., *E. vellicatus* Cush., *Holocremmus ratzeburgi* (Tschek), *Lamachus eques* (Htg.), *L. marginatus* (Brischke), *L. spectabilis* (Holmg.), *Lamachus* sp., *Lophyprolectus luteator*, *Monodontomerus dentipes* (Dalm.), a species of Euryproctini near the genus *Zemiophorus* (Hymenoptera); and *Bessa selecta* (Meig.), *Blondelia inclusa* (Htg.), *Drino bohémica* Mesn., and *D. inconspicua* (Meig.) (Diptera). Those from Japan were *Exenterus adspersus* Htg., *Lamachus albopictus* Cush., *Lophyprolectus* sp., *Monodontomerus japonicus* Ashm. (Hymenoptera) and *Drino* sp. (Diptera). The establishment of introduced species on *D. hercyniae* in Canada was recorded by Baird (1937, 1939, 1940, 1941), Balch

TABLE V

Hosts and countries of origin of introduced species that have become established in Canada on *Diprion hercyniae*

Species established	Hosts	Country of origin
<i>Aptesis basizonia</i> (Grav.)	<i>Diprion frutetorum</i> (F.) <i>Diprion pallidus</i> (Klug) <i>Diprion pini</i> (L.) <i>Diprion polytomum</i> (Htg.) <i>Diprion similis</i> (Htg.) <i>Neodiprion sertifer</i> (Geoff.)	Czechoslovakia Czechoslovakia Germany, Holland Czechoslovakia Poland Czechoslovakia, Esthonia, Hungary, Sweden
<i>Aptesis subguttatus</i> (Grav.)	<i>Diprion similis</i> (Htg.) <i>Neodiprion sertifer</i> (Geoff.)	Poland Hungary, Czechoslovakia
<i>Dahlbominus fuscipennis</i> (Zett.)	<i>Diprion frutetorum</i> (F.) <i>Diprion pini</i> (L.) <i>Diprion polytomum</i> (Htg.) <i>Diprion similis</i> (Htg.) <i>Neodiprion sertifer</i> (Geoff.)	Czechoslovakia Holland Czechoslovakia Poland Czechoslovakia, Esthonia, Hungary
<i>Drino bohémica</i> Mesn.	<i>Diprion polytomum</i> (Htg.)	Finland, Sweden
<i>Exenterus amictorius</i> (Panz.)	<i>Diprion frutetorum</i> (F.) <i>Diprion pallidus</i> (Klug) <i>Diprion similis</i> (Htg.) <i>Neodiprion sertifer</i> (Geoff.)	Czechoslovakia Czechoslovakia Poland Czechoslovakia, Esthonia, Hungary
<i>Exenterus confusus</i> Kerr.	<i>Diprion polytomum</i> (Htg.) <i>Neodiprion sertifer</i> (Geoff.)	Czechoslovakia, Finland, Sweden Esthonia
<i>Exenterus tricolor</i> Rom.	<i>Diprion polytomum</i> (Htg.) <i>Lygaeonematus abietinus</i> Chr.	Czechoslovakia, Finland, Norway, Sweden Czechoslovakia
<i>Exenterus vellicatus</i> Cush.	<i>Diprion polytomum</i> (Htg.)	Czechoslovakia



(1940, 1941, 1942), Briand (1947), and Reeks (1952, 1953). According to Reeks (1953), the species that are established are *A. basizonia*, *D. fuscipennis*, *D. bohémica*, *E. amictorius*, *E. confusus*, *E. tricolor*, and *E. vellicatus*. Records at Belleville show that *A. subguttatus* has been recovered from cocoons collected at Parke Reserve, Quebec. The established species with the hosts and the countries from which they were obtained are listed in Table V.

#### Summary

Parasites were reared from about 31,384,000 cocoons of nine species of spruce- and pine-feeding sawflies collected in Europe and Japan, and from half a million eggs of *Neodiprion sertifer* (Geoff.) from Europe. A total of 96 species of primary and secondary parasites were reared from the hosts. The abundant species from *N. sertifer* cocoons from Hungary, Czechoslovakia and Sweden were *Exenterus abruptorius* (Thunb.), *Aptesis basizonia* (Grav.), *Lamachus eques* (Htg.), and *Lophyroplectus luteator* (Thunb.). In addition to these *Exenterus amictorius* (Panz.) was abundant on *N. sertifer* in Esthonia. From *N. sertifer* collected in Japan the main parasites were *Lophyroplectus* sp., *Drino* sp., *Exenterus abruptorius* and *E. adpersus* Htg. The abundant parasites from *Diprion similis* (Htg.) cocoons from Poland were *Aptesis subguttatus* (Grav.) and *E. amictorius*. The parasites from the *N. sertifer* eggs were *Achrysocharella ruforum* (Krausse) and *Tetracampe diprioni* Ferr. The recovery of *A. subguttatus* is a new record for an introduced parasite on *Diprion hercyniae* (Htg.) in Canada.

#### Acknowledgments

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### An Artificial Diet for Rearing Coccinellid Beetles<sup>1</sup>

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One of the most important factors limiting the use of coccinellid beetles in the biological control of certain insect pests is the difficulty experienced in rearing sufficient quantities. The standard method of rearing them on suitable hosts is often impracticable because of their restrictive diets. Such difficulties were encountered when the introduction of some coccinellid beetles was attempted in French Morocco, as a control measure for a coccid (*Parlatoria blanchardi* Targ.) on date trees. The problem of rearing or obtaining the host in sufficient quantity greatly hampered the production of the predators. For this reason, considerable time and effort was devoted to the development of a satisfactory and economic technique for the breeding of these predators on artificial media.

Several formulae were tried with different nutrients. Some gave very poor results in that they proved lethal or had a repellent action. However, the medium which gave best results, and the one which was finally adopted, consisted basically of cane sugar, honey, agar, and royal jelly. The royal jelly is essential to the formula. Presumably, it enriches the medium by virtue of its growth stimulating factors (vitamins and yeast) and, because of its asptic qualities, prevents development of bacteria and other harmful microorganisms. It is prepared as follows: Dissolve 1.3 gm. of agar, 16 gm. of cane sugar and 6 gm. of honey in 100 gm. of hot water and cool to 35-38°C. Separately, add 4.5 gm. of royal jelly to 20 c.c. of the original mixture, and stir constantly until a homogeneous white emulsion is obtained. Combine the two and add 0.5 gm. of alfalfa flour yeast and 2 gm. of pulverized dry insects which are natural prey of the species to be reared. Stir vigorously and cool 5°C. for storing. Slight variations in the above quantities will not affect its stability. The main object is to obtain a medium which should, when cool, be of medium density, neither too hard nor too soft. This diet has proved excellent for the rearing of adult coccinellids, but for the larvae of some species it should be supplemented with three parts beef jelly and one part royal jelly.

<sup>1</sup>Contribution No. 478 Forest Biology Division, Science Service, Department of Agriculture, Ottawa, Canada.

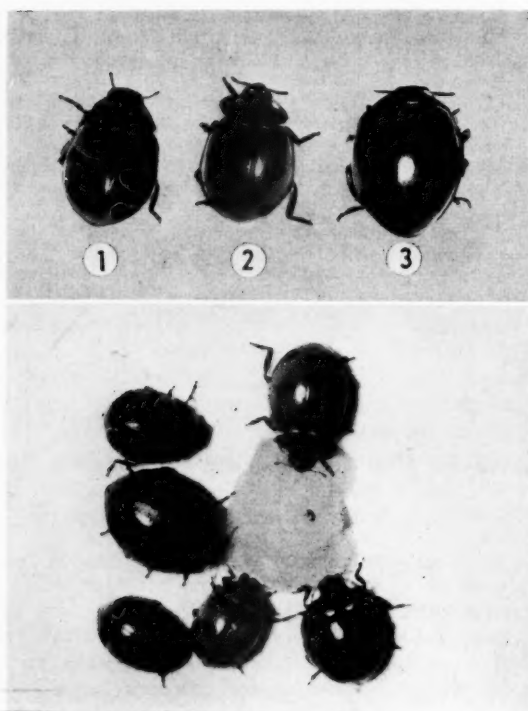


Figure 1. Feeding of coccinellid adults on artificial food.

1. *Coccinella trifasciata* L.,
2. *C. transversoguttata* Fald.,
3. *C. novemnotata* Hbst.

The medium should be fed to the insects at a temperature of 27-30°C., and a relative humidity of 60-80 per cent in the form of small crumble or pellets about 5 cm. in diameter which should be deposited on a piece of white paper. Coloured paper, especially yellow or purple, acts as a repellent. It has also been observed that certain species of coccinellids eat more readily when their food is covered with a piece of paper under which they find protection. Petri dishes make satisfactory rearing chambers.

To date, the following species of coccinellids have been reared successfully on these two artificial media: *Thea vigintiduopunctata* L., *Coccinella septempunctata* L., *Harmonia doublieri* Muls., *Harmonia conglobata* L., *Rhizobius lophantae* Blaisd., *Rhizobius litura* Fab., *Rodolia cardinalis* Muls., *Exochomus anchorifer* All., *Exochomus quadripustulatus* L. var. *floralis* Motsch., *Exochomus nigromaculatus* var. *nigripennis* Er., *Scymnus suturalis* Thung., *Scymnus kiesewetteri* Muls., *Stethorus punctillum* Weise, *Chilocorus bipustulatus* L., *Scymnus pallidivestis* Muls., *Clitostethus arcuatus* Rossi, *Pharoscyrmus numidicus* Pic, *Pharoscyrmus ovoideus* Sic., *Mycetaea tafilaetica* Smirn.<sup>2</sup>

All these species developed more rapidly and the life-span for many was much longer than for those reared under natural conditions (Table 1). Furthermore,

<sup>2</sup>Family Endomychidae

TABLE I.  
Comparison of the Longevity of Some Adult Coccinellidae when Fed Artificial  
Media as Opposed to Natural Food

Species	Longevity of adults in days			
	Annual generation reared	With natural food	Without food	Fed artificial diet
<i>Exochomus nigromaculatus</i> Er.	III	20	5-10	20
<i>Thea vigintiduopunctata</i> L.	II	30	10	150
<i>Scymnus pallidivestis</i> Muls.	II-III	20-30	5-10	120
<i>Scymnus kiesenwetteri</i> Muls.	III	30-45	10-15	180-210
<i>Pharoscymnus ovoideus</i> Sic.	III	20	5	15-20
<i>Mycetaca tafilaetica</i> Smirn.	II	20-40	10-15	120-140

the adults were more active in that they moved more quickly, flew more frequently, and mated more readily.

Gravid females exclusively fed on this medium refused to lay eggs when left in petri dishes. However, when they were transferred to larger cages containing a small twig of the plant on which the species is ordinarily found in nature, oviposition occurred readily.

The use of the artificial medium has proved extremely advantageous for the mass rearing and retention of coccinellids in the laboratory. Also, when transporting the predators over long distances, the use of this artificial medium eliminates the necessity for the simultaneous transportation of the noxious host.

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## Insects Captured in Light Traps With and Without Baffles<sup>1</sup>

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For several years the writer has studied the effects of variations in insect light trap designs on the species and numbers of insects captured. Among these variations are the value of baffles. During the summer of 1957 two traps were operated adjacent to each other in State College. The positions of these traps were alternated every other night. One trap, which has been designated as the Pennsylvania insect-light trap<sup>2</sup> with four interesting baffles, 5 x 20 inches, a 12-inch funnel and a 15-watt black-light fluorescent lamp, was used. The other trap was similar except the baffles were omitted and the trap was held together by means of four small wires.

<sup>1</sup>Authorized for publication on March 31, 1958 as paper No. 2245 in the journal series of the Pennsylvania Agricultural Experiment Station.

<sup>2</sup>Frost, S. W. 1957 The Pennsylvania insect-light trap. Journ. Econ. Ent. 50: 287-292.

### Insects Captured in Light Traps at State College, Pa. 1957 6 Nights August 26-31

Insects	With Baffles	Without Baffles	Notes
Nemocera	43	31	4 families
Brachycera	165	70	6 families
Midges	1424	748	5 families, not separated
Aphididae	291	198	
Cicadellidae	615	380	
Misc. Homoptera	93	51	Chiefly Fulgoridae, Psyllidae
Miridae	326	111	
Misc. Hemiptera	31	30	Chiefly Lygaeidae, Coriidae
Coleoptera	1086	777	9 families largely micros.
Pyralidae	55	33	
Crambidae	390	226	
Geometridae	26	12	
Noctuidae	313	246	
Tortricidae	153	115	
Misc. Macrolepidoptera	78	34	Chiefly Arctiidae, Sphingidae
Microlepidoptera	224	80	
Macrotrichoptera	271	221	
Microtrichoptera	120	30	
Hymenoptera	73	108	Chiefly parasitic forms
Misc. Insects	303	51	Chiefly Neuroptera, Ephemerida
Totals	6480	3552	



In summarizing the results, many groups, showing relatively small catches, have been combined in the table. A few of these insects might be mentioned. Twenty-nine Culicidae came to the trap with baffles, 18 to the trap without baffles, 58 Carabidae were taken in the trap with baffles, 37 in the trap without baffles. Only 9 codling moths were taken from the two traps. Although Phyllophaga were not flying during this season of the year, past experience has shown that baffles were essential to trap large numbers of these insects. Even larger funnels and baffles were desirable.

About twice as many insects were captured in the trap with baffles. Some differences should be noted. The macrotrichoptera and the macrolepidoptera, with the exception of the Crambidae, were attracted in about equal numbers to both traps. More Hymenoptera were taken in the trap without baffles. These were chiefly parasitic species and the numbers were somewhat insignificant. It is apparent that baffles are essential and it is suspected that slight differences in the size or number of baffles would make little difference in the catches.

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### Note on Two Forms of *Hypolithus bicolor* Esch. (Coleoptera : Elateridae)<sup>1</sup>

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Collection and rearing records for 1951 to 1954 indicate that a parthenogenetic and a bisexual form of *Hypolithus bicolor* Esch. occur in Saskatchewan.

Near White Fox, in the northeastern area of the Mixedwood Section<sup>3</sup>, approximately 2,000 beetles were collected from their hibernation cells in the soil and from the soil surface, in fields of native sod, summer-fallow, and crop, at various times during the frost-free periods. All the beetles were female. Sixty beetles reared from larvae collected in this area were also females. Similarly, there were no males in a collection of approximately 300 beetles from near Meadow Lake, in the northwestern area of the Mixedwood Section, and in numerous smaller collections made in other parts of this section. Eleven beetles, all females, were reared from eggs laid by beetles of this parthenogenetic form collected near White Fox during the last week in May, 1952. After a storage period of four months at 38°F., seven of these first generation beetles laid viable eggs without mating. No attempt was made to rear the second generation larvae to the beetle stage.

Of 104 beetles collected from their hibernation cells in the soil near Saskatoon, Rosthern, and Cochin, in the Aspen Grove Section<sup>3</sup>, and Swift Current, in the Grassland Formation<sup>3</sup>, 53 were females and 51 were males. Eleven female and nine male beetles were reared from larvae collected near Saskatoon. In numerous small collections made in several other parts of the Aspen Grove

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<sup>3</sup>Classification by Halliday, W. E. D. 1937. A forest classification for Canada. Canada Dept. Mines Res., For. Surv. Bull. 89.

Section and the Grassland Formation, the sexes were also in a ratio of approximately 1:1. Beetles of this bisexual form were observed to mate, but whether they can also reproduce parthenogenetically was not determined.

Limited collections near the boundary between the Aspen Grove and Mixed-wood sections indicated that there is a zone of intergradation of the two forms between these sections, and that the female to male ratio varies in this zone but always exceeds 1:1. The parthenogenetic form was usually associated with the Puget Sound wireworm, *Ctenicera aeripennis aeripennis* (Kby.), and the bisexual form with the prairie grain wireworm, *C. a. destructor* (Brown). The latter usually occurred also in the zone of intergradation.

There are no apparent differences in external morphology between the two forms. The genetic and physiologic aspects of their reproductive processes were not investigated.

In Alberta, in the spring of 1952, 200 beetles of *H. bicolor* were collected from the soil surface in a summer-fallow field near Lethbridge, in the western portion of the Grassland Formation, within two days after they had emerged from their hibernation cells. Of these, 186 were females and 14 were males. In the Grassland Formation of Saskatchewan, when beetles of this species were collected in a similar manner, the sex ratio was approximately 1:1. This suggests that the Alberta collection is from a zone of intergradation of the parthenogenetic and bisexual forms. The association of the forms of this species with the subspecies of *C. aeripennis* observed in Saskatchewan, if applicable to southern Alberta, suggests that the parthenogenetic form occurs in the Montane Forest Region<sup>a</sup> west of Lethbridge, where *C. a. aeripennis* is found, that the bisexual form occurs in the Grassland Formation east of Lethbridge, where *C. a. destructor* is found, and that the zone of intergradation is in the western portion of the Grassland Formation near Lethbridge, where *C. a. destructor* is also found.

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